

Electrical and Electronic Waste Management in Benin: Socio-Environmental and Economic Practices of Households and Professionals

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Abstract

The awareness of the environmental impact of managing electrical and electronic equipment waste is an increasingly pressing concern for many surveyed households. This study aims to explore the socio-economic aspects and environmental impacts of the practices of households, waste recoverers, and repairers involved in managing electrical and electronic equipment waste in Benin. Eight hundred and forty-one (841) individuals were surveyed, including six hundred and one (601) heads of households from various socio-economic backgrounds, one hundred and twenty (120) waste recoverers, and one hundred and twenty (120) repairers responsible for workshops on electrical and electronic equipment, distributed across three major cities in the country. Data collection, tailored to the characteristics of each target group, was conducted over ninety (90) days in the three cities. Quantitative data underwent statistical analyses, including correlation tests, variance analyses, and descriptive statistics. Our results reveal that 40.12% of respondents consider the environmental impact to be significant. Additionally, 45.12% reported having opted for the repair of an electronic device rather than purchasing a new one. The waste recoverers noted improvements in cleanliness (30.12%) and a reduction in land-fill waste (35.30%). Notably, the majority of waste recoverers (70.48%) expressed an interest in training programmes on sustainable electronic waste management, indicating a desire for improvement and professionalisation in their field. Furthermore, 40.25% of the repairers surveyed identified the procurement of spare parts as a major challenge, with a lack of technical information (25.16%). The findings have facilitated the proposal for the establishment of a transversal electronic waste management unit, UTG521.

Keywords

E-Waste, Circular Economy, Sustainability, Environmental Impact, Toxic Equipment

1. Introduction

New consumption habits are generating new types of waste, among which are electrical and electronic equipment waste, classified as special or hazardous waste. According to Tuncuk et al. (2012) and Hira et al. (2018), electrical and electronic waste refers to discarded electronic devices and all their components. If these wastes are not properly managed, they can have significant environmental and health impacts (Odeyingbo et al., 2019; Li et al., 2018). Heavy metals, chemicals, and plastics present in electrical and electronic waste can contaminate soil, groundwater, and air, adversely affecting the health of communities, particularly in rapidly expanding urban areas (Dasgupta et al., 2023). However, despite their hazardous nature, electrical and electronic waste also contains precious metals that are integral to the manufacturing of certain components, such as copper, gold, and plastics. This represents infinite economic opportunities when management is based on a circular economy, one of the pillars of which is the valorisation of waste governed by a scientific approach. Estimating e-waste is challenging in African countries due to the uncontrolled entry of most new and second-hand equipment.

In Benin, a West African country, there has been rapid growth in the stock of electrical and electronic equipment in recent decades, following a national policy of technological development. While these materials have improved the daily lives of Benin's citizens, the management of electrical and electronic waste largely relies on informal actors, including households, waste recoverers, and repairers. These actors play a crucial role in the electronic waste management chain, often in the absence of stringent regulations and formal collection and recycling systems (Nawaz et al., 2021; Ali et al., 2021). Households, primary producers of this waste, are responsible for its accumulation and storage before disposing of it in informal collection circuits. Waste recoverers, often operating under precarious conditions, recover reusable or recyclable electronic components, while repairers extend the lifespan of equipment through repairs, thereby indirectly reducing the amount of waste generated (Baldé et al., 2017; Topanou et al., 2023; Frantz et al., 2024). These informal practices, while essential for managing electrical and electronic waste, are often misunderstood and underestimated in public policies, which tend to favour centralised and technological solutions without considering the social and economic realities of local actors (Dasgupta et al., 2023). Several studies indicate that synergies between informal and formal circuits in the management of electrical and electronic waste can develop more effective and sustainable systems (Bhaskar & Kumar, 2019; Andeobu et al., 2023). It is in this dynamic that the study

aims to better understand the specific contributions of households, waste recoverers, and repairers in the management of electrical and electronic waste in Benin. This study seeks to illuminate the practices of the various actors involved in the sustainable management of e-waste, as well as their aspirations, by exploring the socio-economic aspects and environmental impacts. By analysing their practices, this study proposes an integrated approach that combines both formal and informal management of electrical and electronic waste considering the social and economic dimensions of the involved actors.

2. Materials and Methods

2.1. Study Area

The study is conducted in Benin, located in West Africa within the tropical zone and located between the equator and the Tropic of Cancer (between latitudes 6° 30' and 12° 30' north and longitudes 1° and 30° 40' east) (Figure 1).

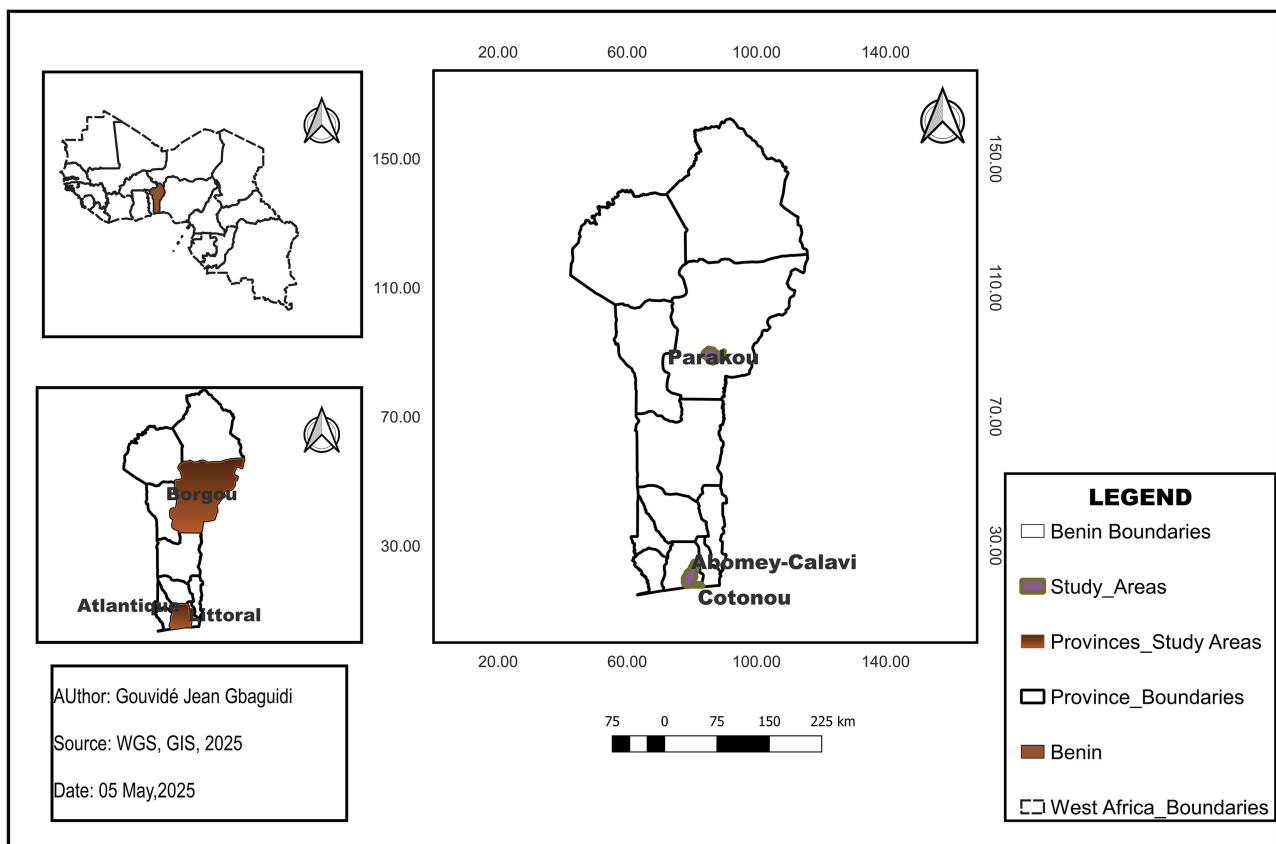


Figure 1. Study areas.

Covering an area of 112,622 km², the Republic of Benin is bordered to the north by the Niger River, which serves as a natural boundary with the Republic of Niger; to the northwest by Burkina Faso; to the west by Togo; to the east by Nigeria; and to the south by the Atlantic Ocean (Figure 1). A careful selection of geographical areas was conducted to reflect the diversity of urban and rural contexts within

Benin, including densely populated areas and more peripheral regions. Three cities in Benin were selected for this study: Cotonou, Abomey-Calavi, and Parakou.

2.2. Survey Population

The study population was selected with the aim of representing various actors involved in the lifecycle of electrical and electronic equipment waste (EEEW) and ensuring diversity within each group, thereby reflecting the varied realities of the Beninese context. The total surveyed population consists of eight hundred and forty-one (841) individuals distributed across the three major cities, comprising six hundred and one (601) households from different socio-economic backgrounds, one hundred and twenty (120) waste recoverers, and one hundred and twenty (120) repairers responsible for workshops on the repair of electrical and electronic equipment. Each target group was approached specifically to gather relevant data pertaining to their respective roles in the management of EEEW (**Table 1**).

Table 1. Sampling of the survey population.

N°		Parakou	Calavi	Cotonou	Total
1	Households	201	200	200	601
2	Repairers	40	40	40	120
3	Recoverers	40	40	40	120
	Total	281	280	280	841

The selected households are residents of the chosen geographical areas who use electronic equipment and have consented to participate in the survey. A representative number of households was selected from each geographical area. The waste recoverers are individuals engaged in the collection of materials derived from electrical and electronic equipment waste, making it an economic activity. The surveyed repairers operate workshops and are involved in the repair of electrical and electronic equipment. KoboToolbox was used for the survey. During the survey, respondents were free to conduct the interview and answer the questions at their own pace. We began by explaining the purpose of the study and obtaining their consent before delving deeper into the questionnaire (lines 124-126).

2.3. Data Collection

Sampling was stratified to reflect socio-economic diversity. The survey questionnaires were meticulously developed to comprehensively capture the perspectives of households, repairers, and waste recoverers. Data collection, adapted to the characteristics of each target group, was conducted over a period of ninety (90) days in the three cities (**Figure 1**).

2.4. Data Processing

The analysis of the collected data was conducted using the Statistical Package for

Social Sciences (SPSS) version 25. Quantitative data underwent statistical analyses, including correlation tests, variance analyses, and descriptive statistics. This allowed for the identification of significant trends and correlations between different variables. Qualitative data obtained from interviews were subjected to thematic sorting analysis, which categorised the information based on recurring themes that emerged organically from the participants' responses.

3. Results and Discussion

3.1. Results

Perceptions of Actors in EEEW Management

Table 2 presents the environmental challenges associated with the management of EEEW. The analysis of this table reveals that perceptions of the various groups surveyed regarding environmental challenges vary from one group to another.

Table 2. Environmental challenges in the management of EEEW.

N°	Questions	Responses	Cotonou	Abomey-Calavi	Parakou	Average
1	To what extent do you consider the environmental impact when managing your Waste Electrical and Electronic Equipment (WEEE)?	Not at all	5.11	5.16	4.71	4.99
		Slightly	15.02	15.02	14.90	14.98
		Moderately	24.92	24.88	25.10	24.97
		Very much	39.94	39.91	40.39	40.08
		Extremely	15.02	15.02	14.90	14.98
2	What environmental factors are most important to you when managing WEEE?	Reduction of electronic waste	41.99	41.78	42.19	41.99
		Appropriate recycling	17.95	18.08	17.97	18.00
		Repair to extend lifespan	17.95	18.08	17.97	18.00
		Minimisation of carbon footprint	13.14	12.91	12.89	12.98
		Other	8.97	9.15	8.98	9.03
3	To what extent are you aware of the environmental impact of EEEW?	Very aware	24.8	24.77	25.29	24.95
		Fairly aware	35.2	34.86	34.48	34.85
		Slightly aware	24.8	24.77	25.29	24.95
		Not at all aware	15.2	15.60	14.94	15.25
4	To what extent do you believe that the recovery of electronic waste contributes to reducing environmental impact?	Significantly	20	20.00	20.45	20.15
		Moderately	30	29.23	29.55	29.59
		Slightly	40	40.00	40.91	40.30
		Don't Know	10	10.77	9.09	9.95
5	Have you observed positive changes in the local environment as a result of your recovery activities?	Improvement in cleanliness	40.00	39.58	39.39	39.66
		Reduction of waste in landfill	33.33	33.33	33.33	33.33
		Increased awareness of waste management	26.67	27.08	27.27	27.01

Household Perceptions

According to the survey results, 40.12% of respondents reported a significant consideration of environmental impact, while 15.2% indicated a lesser degree of consideration. Furthermore, our findings reveal that households adopt purchasing behaviours guided by sustainable considerations, prioritising criteria such as energy consumption (27.02%) and durability (38.10%). Additionally, 45.12% stated they had previously opted to repair an electronic device rather than purchase a new one. These results highlight a widespread willingness to extend the lifespan of electronic and electrical equipment. The preference for repair over replacement indicates a growing awareness of the importance of sustainability.

Perceptions of Waste Recoverers

Opinions vary regarding the contribution of electronic waste recovery to reducing environmental impact. Only 20.48% believe it contributes significantly, while 40.96% think its impact is minimal. Nevertheless, waste recoverers have observed some positive changes in their local environment as a result of their activities. They noted improvements in cleanliness (30.12%), a reduction in landfill waste (35.30%), and increased awareness of waste management (20.48%) as notable changes (**Table 2**).

Waste recoverers identify opportunities in the recovery of EEEW. 35.54% view income potential as a major opportunity, followed by local job creation (30.12%) and contributions to sustainability (25.30%). Notably, the majority of waste recoverers (70.48%) express interest in training programmes on sustainable electronic waste management, underscoring a desire for improvement and professionalisation in their field. Furthermore, they suggest that certain initiatives could enhance EEEW management, mentioning the establishment of recovery cooperatives (25.10%), community awareness campaigns (20.48%), and integration into formal recycling chains (15.06%) as potential strategies (**Table 2**).

Perceptions of Repairers

Survey results from repairers indicate that, despite their daily proximity to EEEW, a significant portion of repairers is only minimally or not at all aware of the environmental impact of this waste. Only 25.16% consider themselves very aware of these impacts, while 40.57% reported being somewhat or not at all aware (**Table 2**). Our study highlighted several major challenges faced by repairers in their activities related to electronic and electrical waste (**Table 2**). Among these challenges, 40.25% cited the procurement of spare parts as a primary obstacle, followed by a lack of technical information (25.16%) and a lack of socio-professional recognition (20.13%).

Analysis of Socio-Economic Sustainability in Electronic Waste Management

Table 3 illustrates socio-economic sustainability by considering, on one hand, the sensitivity to sustainability among various actors involved in the production, repair, or recovery of electronic and electrical equipment waste, and on the other hand, their attitudes towards repair practices, as well as the challenges of the circular economy.

Table 3. Sensitivity to sustainability.

N°	Questions	Response options	Cotonou	Ab-Cal	Parakou	Average
1	What criteria are most important to you when purchasing new electronic equipment?	Price	7.94	7.98	7.84	7.92
		Brand	4.13	3.99	3.92	4.01
		Technical specifications	3.17	3.05	2.75	2.99
		Energy consumption	26.67	27.00	27.06	26.91
		Product lifespan	37.78	37.79	38.43	38.00
		Repairability	19.05	19.01	19.22	19.09
		Environmental labels	1.27	1.17	0.78	1.08
2	What are the main obstacles that might prevent you from purchasing more sustainable electronic products?	High cost	19.11	19.01	19.14	19.09
		Lack of information on product sustainability	43.63	43.90	44.14	43.89
		Lack of sustainable options in the market	28.03	27.93	28.13	28.03
		Perception of inferior performance of sustainable products	6.05	6.10	5.86	6.00
		Other	3.18	3.05	2.73	2.99
3	How important is it to you that your electronic equipment can be repaired in the event of a failure?	Not at all important	5.10	5.16	4.71	4.99
		Slightly important	14.97	15.02	14.90	14.96
		Neutral	20.06	19.95	20.00	20.01
		Important	39.81	39.91	40.39	40.04
		Very important	20.06	19.95	20.00	20.01
4	Have you ever had an electronic device repaired instead of buying a new one?	Yes	44.87	45.05	45.14	45.02
		No	25.00	25.00	24.90	24.97
		Unsure	30.13	29.95	29.96	30.01

From the analysis of this table, it is evident that consumption habits, lived experiences, and social status significantly influence the purchasing criteria for electrical and electronic equipment (EEE). These criteria are often interdependent. Seven key criteria have been identified as the most important when purchasing an EEE (see **Table 3**). Among these criteria, the product's lifespan (38%), the possibility of repair (19.09%), and its energy consumption capacity (26.91%) are the most decisive factors when acquiring an electronic waste item. The surveyed population appears to be more inclined to purchase products that offer a long lifespan, regardless of price (7.92%), brand (4.01%), or technical specifications (2.99%). These responses are notably consistent across all cities where the survey was conducted, indicating that consumers, on average, place significant importance on the longevity of the EEE they purchase.

Moreover, 43.89% of the surveyed population believes that a lack of information regarding the sustainability of products is the primary barrier preventing them from purchasing more sustainable electronic goods. Over 60% of respondents in each of the three cities consider it important that electronic equipment can be repaired in the event of a malfunction.

Challenges and Opportunities for a Circular Economy in the Repair of Electronic and Electrical Equipment

Table 3 presents the challenges associated with the repair of electronic and electrical equipment waste. This table reveals a strong correlation between the expectations of the surveyed population and the proportion (45%) of this same population that indicates having previously repaired an electronic device rather than purchasing a new one. Consumers prefer to have all the necessary information to purchase a quality product that they can repair in the event of a malfunction. The results confirm that consumers exhibit a significant sensitivity to the sustainability of their purchases of electronic and electrical equipment.

The table also shows that nearly 65% of repairers surveyed in each of the three cities face difficulties related to the procurement of spare parts. Within the framework of a circular economy, establishing a policy for acquiring replacement parts would be highly beneficial. In fact, 24.97% of the surveyed population suggests that a financial incentive, such as a discount on the purchase of new equipment, would be motivating, while 30% advocate for the implementation of a buy-back policy for spare parts. Finally, it is noteworthy that there exists a potential market driven by a demand exceeding 75% for recovered materials in the local market.

3.2. Discussion

Sustainable management of electronic and electrical equipment waste, as perceived by the various surveyed stakeholders, revolves around socio-economic sustainability and socio-environmental sustainability. Socio-environmental sustainability should remain the guiding principle of all waste management policies. Our results reveal that over 55% of respondents consider the environmental impact when managing electronic and electrical waste, reflecting a significant level of environmental awareness within the population and indicating a better engagement in waste management. Furthermore, our findings indicate that over 55% of respondents actively consider the environmental impact when managing electronic and electrical waste. This finding reflects a significant level of environmental awareness among the population and suggests a growing engagement in sustainable waste management practices. Previous studies have shown that increased awareness of environmental issues can lead to more responsible consumer behavior and improved waste management strategies (Ackah, 2019). The high percentage of respondents acknowledging environmental impacts indicates a positive shift towards more sustainable attitudes and practices in electronic waste management.

Moreover, the fact that 41.99% of the surveyed population identifies reducing the quantity of electronic waste produced as the most important environmental factor further highlights the emphasis on prevention in waste management strategies. This preference aligns with the principles of waste hierarchy, which prioritize waste reduction as a fundamental strategy for achieving sustainability. By focusing on minimizing waste generation, consumers contribute to reducing the

environmental burden associated with electronic waste, thereby promoting a more sustainable lifecycle for electronic products.

The results also suggest that the population's engagement in waste management is influenced by a combination of awareness and personal responsibility. Studies have indicated that when individuals perceive their actions as impactful, they are more likely to engage in environmentally friendly practices. The recognition of the environmental consequences of electronic waste may motivate individuals to adopt behaviors that support waste reduction, recycling, and responsible disposal.

Furthermore, this level of awareness presents an opportunity for policymakers and stakeholders to enhance educational initiatives aimed at promoting sustainable waste management. By providing information and resources about the environmental impacts of electronic waste and strategies for reduction, stakeholders can empower consumers to take more proactive roles in managing their electronic waste.

On the other hand, 38% prioritise lifespan, 19.09% consider the possibility of repair, and 26.91% focus on the product's energy consumption capacity when purchasing electronic waste items. The surveyed population appears more predisposed to acquiring products with a long lifespan, regardless of price (7.92%), brand (4.01%), or technical specifications (2.99%).

The survey results reveal that 59.8% of respondents are somewhat aware of the environmental impact of electronic and electrical waste (e-waste) and have observed positive changes in their local environment due to various activities. This level of awareness is encouraging, suggesting that community engagement and educational initiatives have had a meaningful impact on environmental consciousness. Previous studies have shown that increased awareness often correlates with proactive behavior in environmental management, as individuals recognize their role in contributing to local sustainability efforts (McKenzie-Mohr, 2000; Kollmuss & Agyeman, 2002).

Specifically, 39.66% of respondents noted improvements in cleanliness, while 33% reported a reduction in landfill waste. These observations indicate that community efforts in waste management and recycling are yielding tangible benefits, reinforcing the importance of local initiatives in fostering a cleaner environment. Research has indicated that visible environmental improvements can enhance community motivation to participate in sustainability programs (Bennett et al., 2013; Komal et al., 2023).

Furthermore, the results indicate that consumption habits, lived experiences, and social status significantly influence purchasing criteria for electrical and electronic equipment (EEE). Notably, 38% of respondents prioritize product lifespan when making purchasing decisions, indicating a strong preference for durable products. This preference aligns with findings from the literature that suggest consumers are increasingly valuing longevity in products as a means of reducing waste and achieving sustainability (Bocken et al., 2016).

Additionally, 19.09% of respondents consider the possibility of repair, while

26.91% focus on energy consumption capacity. This emphasis on repairability and energy efficiency reflects a broader trend toward sustainable consumption, where consumers are seeking products that not only meet their immediate needs but also contribute to environmental sustainability (Kjaernes et al., 2016).

Interestingly, the surveyed population appears to prioritize lifespan over other factors such as price (7.92%), brand (4.01%), or technical specifications (2.99%). This finding suggests that consumers are willing to invest in quality products that promise durability, indicating a potential shift in consumer values toward sustainability over traditional purchasing criteria. This aligns with the concept of “green consumerism,” where environmental considerations increasingly shape consumer choices (Peattie & Crane, 2005).

The findings from the survey reveal critical insights into consumer attitudes toward sustainable electronic products. Notably, 43.89% of respondents identified a lack of information on product sustainability as a significant barrier to their purchasing decisions. This aligns with previous research indicating that consumer awareness and information accessibility are pivotal in promoting sustainable purchasing behavior (Thøgersen, 2006; Peattie & Crane, 2005). The perception that sustainability information is insufficient suggests a need for manufacturers and retailers to enhance transparency regarding the environmental impacts of their products. Providing clear, accessible information could empower consumers to make informed choices that align with their values.

Additionally, the data shows that over 60% of respondents in each surveyed city prioritize the repairability of electronic equipment. This preference underscores a growing demand for products designed with longevity in mind, reflecting a shift in consumer values toward sustainability. Previous studies have noted that consumers are increasingly aware of the environmental consequences of electronic waste and are seeking alternatives that minimize their ecological footprint (Bakker et al., 2014; Cooper, 2016). This trend aligns with the broader movement toward a circular economy, where products are designed to be reused, repaired, and recycled rather than discarded (Geissdoerfer et al., 2018).

Moreover, the emphasis on having all necessary information to purchase quality products indicates that consumers are not just concerned about sustainability in isolation; they also value the overall quality and functionality of their purchases. This holistic view suggests that sustainability cannot be the sole focus; rather, it must be coupled with assurances of quality and performance to meet consumer expectations (Ellen MacArthur Foundation, 2013).

Overall, these results confirm that consumers exhibit a strong sensitivity to the sustainability of their purchases in the electronic and electrical equipment sector. This sensitivity presents an opportunity for manufacturers and retailers to innovate and develop sustainable products that meet consumer demands. By addressing the information gap and focusing on repairability and quality, companies can enhance their market appeal and contribute to a more sustainable future.

The inclination towards a better quality/price ratio and products that do not

deteriorate quickly is a positive indicator of socio-economic sustainability in the management of electronic and electrical waste. This management should align with the zero waste objective, which is increasingly based on the 5Rs: Reduce at the source, Repair, Reuse, Recycle, and Reinvent. This strategy encourages consumers, as waste producers, to commit to ensuring that their waste does not end up in landfills or incinerators. The circular economy finds its place within a participatory waste management system. It calls for the emergence of new professions, such as waste recoverers and repairers, who become key actors in the implementation of a sustainable waste management system for electronic and electrical equipment. This findings highlight the integration of the circular economy within a participatory waste management system, emphasizing the need for new professions such as waste recoverers and repairers. This evolution signifies a shift toward a more sustainable and collaborative approach to managing electronic and electrical equipment waste. The emergence of these roles is crucial for the effective implementation of sustainable waste management practices, as they contribute to resource recovery and waste reduction (Kirchgeorg & Dangelico, 2018).

The concept of a circular economy promotes the idea that waste should not be viewed as a final product but rather as a resource that can be reclaimed and reused. This perspective aligns with the principles outlined by the Ellen MacArthur Foundation (2013), which advocates for designs that facilitate recycling and repair, thereby extending the lifecycle of products. In this context, waste recoverers and repairers play a pivotal role in maintaining the value of materials within the economy, reducing the need for new resource extraction and lessening environmental impacts (Bocken et al., 2016).

Moreover, the participatory aspect of waste management is essential for community engagement and empowerment. By involving local stakeholders in the waste recovery and repair processes, the circular economy fosters a sense of ownership and responsibility toward sustainable practices. This participatory approach has been shown to enhance the effectiveness of waste management systems by promoting collaboration among various actors, including local governments, businesses, and community members (Rogers & Hall, 2003).

Furthermore, the rise of these new professions reflects changing consumer attitudes toward sustainability and the importance of local solutions in waste management. As consumers increasingly seek to engage with sustainable practices, the demand for skilled professionals who can facilitate waste recovery and repair is likely to grow (Moreno et al., 2016). This trend can lead to job creation and economic opportunities within communities, aligning with broader sustainability goals.

Dieng et al. (2017) focused on these new actors in the sector in Senegal, indicating that waste recoverers, who merely transfer electronic and electrical waste from one actor to another, are primarily young individuals. The predominance of those under 40 can be attributed to the high unemployment rate among youth,

leading them to turn to the informal sector, as noted in a World Bank study. The same author reports that these recoverers lack knowledge about the dangers of toxic components in electronic and electrical waste to which they are exposed.

Conversely, Kôkôh et al. (2020) found that in Côte d'Ivoire, only 16% of repairers are aware of health risks, and only 25% use protective measures at work. This explains, according to the same authors, why more than half (54%) suffer from workplace accidents, and 5% experience frequent illnesses. These results further clarify why 25.07% of surveyed recoverers express a need for capacity-building support, compared to 29.82% who request financial assistance to equip themselves.

Moreover, reducing the quantity of electronic waste produced is the most important environmental factor for 41.99% of the surveyed population, in contrast to 18% who consider repair or recovery factors. Therefore, a strategy to reduce the quantity of electronic and electrical equipment waste would be highly appreciated and implemented by the population, as recommended by the works of (Awasthi et al., 2016; Ali et al., 2021), which yielded similar results. However, it is noteworthy that only 20.15% of the population believe that the recovery of electronic waste contributes significantly to reducing environmental impact. Stakeholders should leverage this awareness to promote environmentally friendly practices and support the development of durable, repairable, and energy-efficient electronic products.

Proposal for a Transversal Unit for the Management of EEEW (UTG521)

Our findings underscore the importance of establishing an effective organisation to mitigate the adverse consequences of electronic and electrical waste. The establishment of a transversal waste management unit, referred to as UTG521, is proposed. This unit will comprise five activity areas and two operational cells. The five activity areas will focus on:

Area 1: Collection of Electronic and Electrical Equipment Waste

The establishment of collection points for electronic and electrical waste in various neighbourhoods of the municipality is the first activity to implement. Voluntary contributions from households will be the option to experiment with, as it is more participatory and cost-effective than door-to-door collection.

Area 2: Sorting and Grouping

At this stage, waste recoverers, organised into economic interest groups (GIEs), will sort the collected electronic and electrical waste to separate different types of devices (electrical, household appliances, IT, etc.). They will then group them according to categories to facilitate further processing.

Area 3: Repair

A repair workshop will be established, and repair agents will be further equipped. The previously sorted waste will be subject to potential repair treatment to be reintroduced into the consumption chain.

Area 4: Transport and Delivery

An efficient transport system will be implemented to move the sorted electronic

and electrical waste to treatment centres. Route controls will be enforced to minimise environmental impacts related to transportation.

Area 5: Treatment and Recycling

Treatment centres for recycling and recovering materials from electronic and electrical waste will be established. Environmentally friendly technologies will be used for waste treatment.

The two operational cells are the awareness and education cell and the monitoring and evaluation cell. The primary mission of the first cell will be to organise awareness campaigns to inform about the importance of recycling electronic and electrical waste and the risks associated with poor management. It will also conduct educational workshops in schools and communities to promote environmental responsibility. The second cell will oversee the functioning of a monitoring system to evaluate the effectiveness of electronic and electrical waste management activities and to collect data on the volumes of collected, sorted, treated, and recycled electronic and electrical waste to measure progress and identify areas needing improvement.

A communal management committee for the operation of the UTG521 structure, responsible for managing electronic and electrical waste, would ensure effective collection, sorting, repair, recovery, and appropriate recycling of these devices. This would contribute to reducing pollution and creating a sustainable future for future generations.

Examination of the Feasibility and Potential Impact of the UTG521 Framework

- **Cost-Benefit Analysis**

The UTG521 framework incurs initial setup, operational, and compliance costs, including infrastructure, equipment, staff training, transportation, maintenance, and compliance measures. However, effective management of electronic and electrical waste can reduce pollution, stimulate the local economy, and improve health outcomes. It also fosters community participation, enhancing civic responsibility and environmental awareness.

- **Implementation Challenges**

Implementing the UTG521 framework may encounter several challenges. Encouraging voluntary contributions from households may be difficult initially, requiring effective communication and outreach strategies to build community trust and engagement. Coordination among stakeholders, including local governments, NGOs, and private sector partners, will require significant effort and ongoing negotiation to ensure successful implementation. Training waste recoverers and repair agents will be crucial, as they need to be skilled in handling EEEW safely and effectively. Logistical issues may arise in establishing and maintaining an efficient transport system, particularly in urban areas with traffic congestion or inadequate infrastructure.

- **Regulatory Framework**

The UTG521 framework must adhere to various regulatory requirements, in-

cluding local, national, and international regulations regarding waste management, recycling, and environmental protection. Compliance with laws related to hazardous materials and electronic waste is essential. Establishing collection points and treatment facilities may require various permits from governmental authorities, which can be a lengthy process. Additionally, the monitoring and evaluation cell will need to establish protocols for data collection that comply with regulatory requirements, ensuring transparency and accountability in waste management activities.

- **Potential Impact**

Implementing the UTG521 framework can enhance the municipality's capacity to manage EEEW sustainably, thereby reducing environmental impacts and promoting resource recovery. The awareness and education cell will play a critical role in changing public attitudes towards EEEW, leading to long-term behavioral changes that support sustainability goals. By creating a structured approach to managing EEEW, the framework can contribute to the resilience of the local economy by providing jobs and supporting green technology initiatives.

4. Recommendations

The in-depth study on the management of electronic and electrical equipment waste in Benin generates significant implications for policymakers. The resulting recommendations aim to strengthen the responsible management of electronic and electrical waste in the specific context of Benin. Awareness and education are crucial for the sustainability of the unit. The results highlight the challenges faced by repairers and the vital role of recoverers in the informal collection of electronic and electrical waste. Recommendations include awareness campaigns, financial support for repairers, formal integration of recoverers, and regular evaluations.

In response to challenges such as limited access to spare parts, strategic recommendations can be formulated. These include financial support programmes, partnerships with manufacturers, ongoing training programmes, and the establishment of networks of repairers. Furthermore, integrating informal waste management practices for electronic and electrical waste is necessary. Recommendations encompass the formalisation of recoverers' activities, training and awareness programmes, access to safety equipment, official collection points, ongoing training, regular assessments of working conditions, and access to health services.

Additionally, the establishment of recycling programmes is imperative. The results emphasise the need for dedicated recycling facilities, selective collection systems, and collaborations with specialised companies. The development of supportive policies is also crucial. Recommendations include Extended Producer Responsibility policies, sustainable design standards, strict import regulations, policies promoting repair, and educational campaigns. These recommendations, integrated into existing policies with the engagement of key stakeholders, can contribute to creating a more efficient and environmentally friendly electronic and electrical waste management system in Benin.

5. Conclusion

In light of the findings above, challenges, and perspectives of electronic and electrical waste management at the household, repairer, and recoverer levels in Benin highlight the absence of an organised system for managing this waste. The surveys conducted captured various facets of this waste management, revealing both challenges and opportunities for a sustainable sector. Repairers and recoverers operate in an informal environment and aspire to better socio-economic conditions through a special programme for strengthening technical and material capacities. Integrating informal recovery into electronic and electrical waste management policies is recommended to maximise its positive impact while mitigating health, safety, and environmental risks to communities. The establishment of a structured waste management system for electronic and electrical waste is proposed, based on creating a conducive environment for socio-economic sustainability with minimal environmental impacts while adhering to rules and standards related to collection, recovery, treatment, and recycling.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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