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E-waste management in higher education institutions: insights and policy recommendations

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ABSTRACT

Electronic waste disposal is a primary concern both on a national and global spectrum. The increased usage of information and communication technology and electronic devices among higher education institutions (HEIs) contributes to the annual generation of e-waste. HEIs are called to implement a sustainable scheme to curtail the environmental and public health threats brought by e-waste. Against this background, the recycling strategies of HEIs for discarded electronics were examined and evaluated as to its effectiveness and used as basis to develop policy recommendations for e-waste management. The interventions developed were met with general approval and positive response. The innovative products were perceived to be useful in serving their new purposes and reducing the problems of e-waste in HEIs. These findings provide valuable input for HEIs seeking to enhance their e-waste recycling practices. Existing legislation concerning e-waste was looked into, and policy recommendations that encouraged cooperation and shared accountability among key players and stakeholders were drawn up.

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1. INTRODUCTION

Information and communication technology (ICT) has grown in importance recently, generating indisputable contributions to the economic, educational, and social growth of many nations [1], [2]. ICT is considered an imperative factor in the contemporary economy, which is primarily based on knowledge and information [3], [4]. The massive consumer demand for innovative and more advanced technology resulted in a continual increase in the manufacturing and marketing of electrical and electronic products, especially those associated with ICT- personal computers, laptops, printers, photocopiers, tablets, telephones, teaching aids such as projectors, televisions, and sound systems [2], [3], [5]. Frequent tech advancements, higher household incomes, urbanization, shorter product lifespans, and increased crop disposal fuel the rising demand [6]. Concomitant with the growth in global consumption of ICT equipment and electronic devices is the increasing generation of its waste stream. Electrical and e-waste (WEEE) refers to discarded electrical and electronic goods at the end of their useful lives [7], [8]. At present, e-waste is one of the world's most challenging problems due to the considerable economic losses and the high price incurred for both society and the environment, particularly in underdeveloped countries [9], [10].

Throughout the world, E-waste generation from both developed and developing countries is growing persistently, with average production amounting to 44.7 million metric tons yearly [4], [8]. From this figure, it

can be inferred that each individual contributes roughly 6.1 kg of e-waste per year which is projected to rise to 6.8 kg by 2021 [8]. The hefty volumes of generated e-waste are attributed to the fact that most electronics have reduced lifespan due to rapid technological advancement. The problem emerges when e-waste is not collected or treated in an environmentally responsive means. The World Health Organization (WHO) classified e-waste as hazardous waste as it comprises highly toxic elements such as cadmium, arsenic, chromium, barium, cobalt, copper, lead, selenium, zinc, silver, mercury, and lithium [11]–[13] which can be released into the environment through inadequate and uncontrolled handling and treatment [14]–[16]. The landfilling of waste electrical and electronic equipment along with the municipal solid waste can have adverse environmental impacts, including surface and groundwater contamination by lead leaching, discharge of toxic fumes into the air, leachate of lead due to excessive concentrations and the possibility of uncontrolled fires at landfills [13], [17], [18]. Additionally, crude recycling and improper treatment procedures pose serious human health concerns, as workers are exposed to hazardous and toxic components appended to electronic products [12]. In general, e-waste management is challenging due to the general insufficiency of definite and adequate regulations and weak enforcement of e-waste guidelines in many countries.

By 2030, global e-waste was forecasted to reach 74.7 million metric tons [19]. E-waste has been identified as the type of municipal solid waste (MSW) with the fastest rate of growth due to the high amounts generated around the world, accounting for more than 5% of the overall MSW stream [7]. E-waste management is one of the most critical challenges facing the ICT industry and has emerged as a global issue. The inability of the government in poor nations to handle e-waste effectively is a result of weak monitoring and legislative structures as well as socioeconomic and technical difficulties [20]. Due to the associated environmental, economic, health, and social implications of e-waste, there is a need for sustainable management of electronic and electrical items at the end of their valuable lives [2].

Many nations have taken action to create environmentally and economically viable strategies for the treatment of e-waste. The adoption of extended producer responsibility (EPR), which assigns producers the duty of collecting, recycling, and eventually dumping electronic devices, is one of the most advised e-waste management strategies [21], [22]. EPR concepts have been successfully embedded in the e-waste management regulations of many industrialized countries. Nations in the Asia Pacific region, however, owing to their flimsy regulatory frameworks and cheap labor for recycling e-waste, have been the target disposal points of e-waste streams from developed countries [23]. The Philippines reflects the plight of most developing countries in terms of e-waste, and this problem is compounded by the importation of used and scrap electronics from industrialized nations.

In Indonesia, the Philippines, and Vietnam, e-waste generation is 2-3 kg per person, and by 2030, each country's population will exceed 100 million [24]. In 2019, the country produced a total of 32,664.41 metric tons of e-waste. Despite the notable upsurge in users of ICT devices, electrical and electronic products, the Philippines is fundamentally ill-equipped with proper e-waste disposal practices and facilities, particularly for recycling and reusing outdated devices, and there are no well-established solutions for generated e-waste [25]–[27]. A sizeable proportion of e-waste generated by the Filipino populace is either stored at homes for an undefined period or discarded in municipal waste streams [2], [27]. Government offices, higher education institutes, and other institutions dispose of outdated electronics like computers and laptops through a lengthy bidding process with recyclers. In 2011, there were 119 registered treatment, storage, and disposal (TSD) facilities nationwide, but only 23 were operational, with South Central Mindanao hosting the sole TSD facility.

Efforts to address the rising e-waste problem have been put in place by the Philippine government through legislation that mentions e-waste. However, without a clear and comprehensive directive specifically for e-waste management, implementing national legislation at the local level can be challenging, especially considering the geographical location of the Philippines, which exposes the country to the threats of climate change [28]. For this reason, the present study generally aims to develop a framework of interventions applicable to e-waste generated by higher learning institutions in South Central Mindanao. Specifically, it also seeks to i) identify ways to use and reuse discarded electronic devices from HEIs as a workable e-waste management option, ii) evaluate the effectiveness of the interventions through the viewpoint of teachers and students from the HEIs, and iii) policy recommendations to help decision-makers craft and formulate a comprehensive management system for e-wastes and to urge various key players and stakeholders to have shared accountability towards a more sustainable society.

2. METHOD

Descriptive research was used at the study site in South-Central Mindanao, which is concentrated in the Cotabato Province, which has seventeen municipalities and one component city. E-waste disposal facilities are not yet available in the area. In addition, no research on e-waste management in HEIs in the nation has been done. Scavengers, recyclers, and waste collectors collect non-functional electronics. One hundred twelve

respondents were randomly selected, which included teachers, junior/senior high school, and college students from various educational institutions in South Central Mindanao.

The research instrument consists of 23 items that relate to recycling techniques, the ability of newly developed products to fulfill their intended uses, the general effectiveness of the e-waste intervention in reducing the e-waste problem, and the respondent's level of knowledge regarding the management of e-waste. Experts examined and verified the questionnaires to evaluate their ability to acquire the necessary data and obtain the appropriate recommendations. Prior to the distribution of survey questionnaires, the respondents were advised to watch the video and photos showing the items made from e-waste before answering the survey. Links to Google Forms and YouTube videos showing the products created from discarded electronics were sent to each participant by email. After that, and with the limited interaction due to the pandemic, the survey was designed with the use of Google Forms, which were later sent to the respondents.

A five-point Likert scale was used to capture the participants' views on each item of the questionnaire. The study emphasizes recycling strategies for using e-waste that is beyond repair for other purposes. The proponents developed three categories of products made from discarded electronic devices: instructional materials, art pieces, and planting pots. An assessment of the developed e-waste intervention was subsequently done, encompassing the outlooks of secondary school teachers and students. Descriptive statistics, including frequency, percentage, mean, and ranking, were obtained. The respondents' perceptions of items related to the effectiveness of the developed e-waste intervention were interpreted using the weighted mean scores of the Likert scale.

3. RESULTS AND DISCUSSION

The present study employed descriptive research to delve into the various aspects of e-waste management in higher education institutions in South Central Mindanao. Figure 1 provides a graphical depiction of the multi-phased e-waste management model of HEIs, as deduced from the survey. The model consists of various stages, including distribution of the electronic device, consumption, collection, material recovery, disposal/recycling, development of a framework, assessment, and obtaining results.

The lack of an efficient e-waste management system in higher education institutions in South Central Mindanao, Philippines, prompted this study. Its main goal is to devise a model for e-waste intervention by repurposing non-functional and discarded electronic devices from these institutions to create innovative products for various uses. Three categories of e-waste products were developed using HEI's discarded electronic and electrical equipment: instructional materials, art pieces, and planting pots. Instructional materials that can be useful for hands-on demonstration during classes were created out of obsolete and non-functional CD-ROM, computer mouse, hard disks, system units (motherboard), cellphones, and power supplies. Art pieces and decorations were crafted using an assortment of e-waste. Planting pots were designed from discarded automatic voltage regulator (AVR) cases and system units. Proper desoldering of discarded AVR was observed for safety. Recycling is a vital method for processing materials and obtaining secondary resources [12].

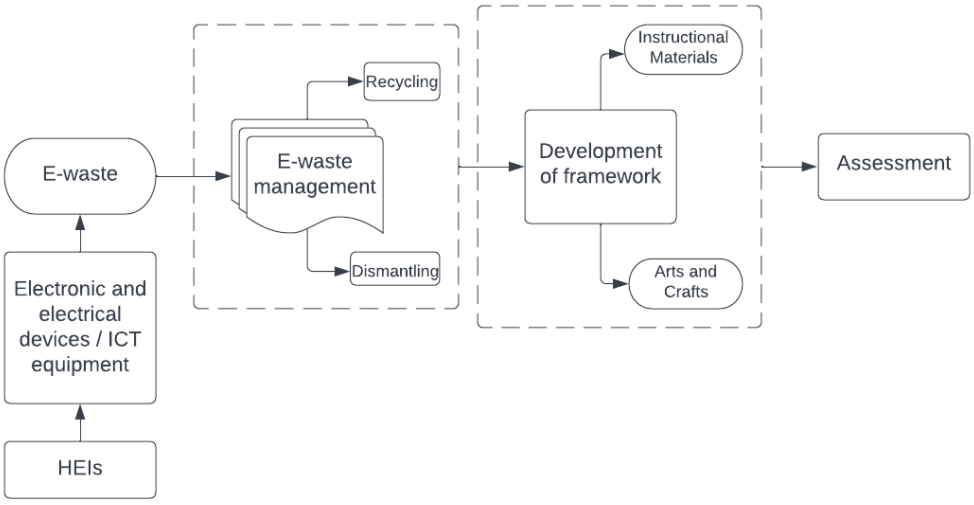

Figure 1. E-waste management model of HEIs

To effectively conduct HEIs' education and research goals, colleges and universities require different types of electronic devices, such as computers, laptops, copiers, printers, projectors, and sound systems. These items become part of e-waste when they are disposed of due to obsolescence, antiquity, and impairment. Generated e-waste by HEIs typically consists of ICT equipment such as a hard disk, system unit, mouse, CD-ROM, AVR case, power supply, and cellular phones, products that have relatively shorter life spans [20]. These items were sorted out, and the researchers identified and produced ways to use each kind of e-waste. Instead of disposing of small electronic appliances, this study encourages the use of such items as raw elements or components to develop instructional materials, art pieces, and planting pots in order to minimize the generation of e-waste.

Positive responses were generally obtained for items relating to the role of the developed e-waste instructional materials in facilitating learning. Participants signified a high level of agreement with the question: "Will students learn more from the instructional materials developed from e-waste?" and "Does the instructional material help in cascading learning to students?" obtaining 52% and 56%, respectively. Favorable responses were also noted when asked about the suitability of various kinds of e-waste, such as hard disks, system units (motherboards), power supplies, CD-ROMs, mice, and cellular phones, as valuable instructional materials. By and large, the captured responses indicate that e-waste was viewed as valuable and can essentially serve as a contrivance for learning. The respondents also expressed their willingness to use e-waste as instructional material, as exemplified by their high scores (27% strongly agreed, while 57% agreed).

The respondents positively accepted the art pieces and decorations made from e-waste. A high proportion of the participants (41%) strongly agreed that the art piece crafted from e-waste is an avenue to develop creativity. They approve of the idea that e-waste can be used to form artistic materials (39% strongly agreed, 52% agreed) and indicated their interest in developing art pieces using e-waste that can be found in their household or offices. Finally, an essential level of agreement was obtained when asked if they were willing to use discarded electronic devices as a form of art; 32% strongly agreed, while 45% agreed.

The respondents' perception of the practicality of e-waste as planting pots was also explored. Respondents showed strong agreement (43%) on the item relating to the utility and handiness of planting pots developed from discarded electronics. However, varying outlooks were obtained when asked if they would purchase such items when made available in the market; 23% strongly agreed, 43% agreed, while others were largely neutral and reluctant to pay for such products. Nonetheless, the majority of the respondents expressed their willingness to purchase recycled e-waste when sold commercially. This is in congruence with the findings of Koshta *et al.* [29], observing that end-users were willing to cover the costs of recycling the e-waste they produce. Positive responses were deduced for questions related to the suitability of e-wastes, such as the system unit case and AVR as raw materials for pots, where 37% strongly agreed while 45-51% agreed. Forty-one percent (41%) strongly agreed that they are inclined to use e-waste matters to create such products. Participants expressed a high level of agreement on the recycling strategy for instructional materials, planting pots, arts, and decorations. Developing new products out of e-waste fosters sustainable innovation and the generation of users and recyclers.

The effectiveness of the recycling strategy for e-waste as a viable option for addressing e-waste through the vantage point of teachers, students, and HEI representatives was also explored. The strong positive perception was mainly observed when asked if the developed products minimize the disposal of e-waste in educational institutions. Over 90% generally agreed that e-waste products developed were considered a suitable recycling method, while more than 86% perceived that e-waste requires special treatment before disposal. Of particular note is the respondents' high level of awareness of WEEE's environmental repercussions. Fifty-two percent (52%) strongly agreed that improper disposal of e-waste may cause harm to the environment.

The disparity in acceptance of developed materials using e-waste based on gender was also looked into in the present study. The overall response patterns are similar for males and females, with marginal variations in the levels of agreement, disagreement, and neutrality. For instance, under the category of instructional materials, the majority of both males and females agree, with males having a slightly higher number of neutral responses compared to females. In the categories of arts and planting pots, the responses are also quite similar, with slightly higher agreement among females compared to males. It's worth noting that the differences between the genders' responses are relatively small and may not indicate significant variations in their attitudes towards e-waste in these specific categories.

The study also evaluated the variations in acceptance of the developed e-waste strategies based on age groups. Respondents aged 15-19 generally have higher agreement levels towards the use of e-waste as instructional materials than the rest of the age groups. The same pattern was observed for both the arts and planting pot categories, mainly attributed to the higher distribution of younger participants in the survey. The planting pots category shows the highest levels of neutrality among respondents in all age groups. In general, respondents across all ages exhibited positive reception to all items developed out of e-waste from HEIs.

The effectiveness of the developed items as viable e-waste management options was also assessed by the participants using the Likert scale. The category of instructional materials has an average rating of 4.08, indicating a generally positive perception from the respondents. The low standard deviation (0.0493) suggests that there is little variability in the responses, signifying that most respondents had a similar opinion about this category. The arts category has a slightly higher mean rating of 4.20, indicating more substantial agreement with statements pertaining to the utilization of e-waste to create arts-related items. The standard deviation of 0.1540 suggests a moderate level of variability in responses, meaning that there may be a range of opinions within this category, although overall sentiment remains positive. The planting pots category has a mean rating of 4.00, indicating general agreement or a positive perception of e-waste related to planting pots. The slightly higher standard deviation of 0.2048 suggests a greater degree of variability in responses compared to the other categories. This means that while the average rating is positive, there may be some divergence in opinions regarding this particular e-waste management strategy.

In general, the participants understood that the products developed from e-waste are good recycling options that can substantially curtail the e-waste disposal problems of HEIs. They were also keen to learn more about e-waste. Knowledge about e-waste management among the respondents was reasonably evident, particularly their awareness of the appropriate treatment before discarding and the harmful environmental impacts of improper e-waste disposal. Their profound understanding is reinforced by their strong support for government e-waste management initiatives. Moreover, it's crucial to intentionally integrate e-waste concerns into the planning processes of government agencies and higher education institutions.

3.1. Challenges in e-waste management in the Philippines

The mounting consumption of electronic and electrical devices in domestic, industrial, and education realms has led to a severe e-waste issue in the Philippines. The escalating e-waste problem in the country primarily stems from the absence of specific legislation on WEEE and weak implementation of the existing regulations. Various researchers also identified other factors contributing to poor management of e-waste in most developing countries, which are also somewhat evident in the Philippines, namely: i) inadequate funds to support recycling improvements and absence of advanced infrastructure for recycling; ii) poorly managed and regulated importation of e-wastes as secondhand devices; iii) absence of formal inventory of e-waste generation; iv) hesitancy of consumers to handover their end-of-life devices due to perceived sentimental value; v) low level of responsiveness among collectors, informal recyclers of the possible perils of improper handling of e-wastes; and vi) lack of environmental awareness about e-wastes [2], [23], [30]–[33].

3.2. Policy directions and recommendation

One of the adverse upshots of industrialization, the rise of communication, and technological advancement is the ever-growing volume of e-waste at national and global scales. Figure 2 shows the framework of policy recommendations for e-waste management in the Philippines. Reflecting the plight of many developing countries, the Philippines is beset with the problem of e-waste and the many banes and setbacks connected to it. This colossal problem poses a serious hazard to both human and environmental health. Hence, e-waste management is an increasing policy concern. In the Philippines, numerous directives have been placed to address the growing issue of e-waste. Since 1990, the country has had a national policy and regulatory framework addressing e-waste, established by Republic Act No. 6969 or Toxic Substances and Hazardous and Nuclear Waste Control. This legislation outlines regulations governing the import, production, handling, storage, trade, use, and disposal of toxic substances and materials containing hazardous components. However, there is no explicit proviso for e-waste. In 1994, the DENR Administrative Order No. 28, Series of 1994, also known as The Interim Guidelines on the Importation of Recyclable Materials Containing Hazardous Substances, was introduced. This directive offers guidance on importing recyclable materials containing hazardous substances, with electronic components and scraps falling within its scope. Republic Act No. 9003, or the Ecological Solid Waste Management Act of 2000, was signed into law in 2001 to set guidelines for the reduction and proper management of solid wastes and designate the collection and handling of special wastes to the local government units. RA 9003 categorized consumer electronics and white goods as "special wastes" that require separate handling from other domestic and commercial wastes. This general law, however, does not have distinct guidelines on how to handle particular waste and lacks a specific framework for e-waste management. DENR Administrative Order No. 22, Series of 2013, was issued in 2013, which categorizes e-waste as a new breed of miscellaneous waste and designates it with waste numbers M506 (WEEE) and M507 (special waste). It stipulates that generators, transporters, and TSD facilities of hazardous wastes, including WEEE, need to be registered with the environmental management bureau (EMB) for proper documentation of the waste movement with necessary permit or the chain-of-custody record. In the same year, House Bill No. 826, also known as the Philippine Hazardous and Radioactive Wastes Management Act of 2013, was crafted to establish a comprehensive management plan for wastes that are hazardous and radioactive in nature. This

directive delineates strategies to reduce the generation of hazardous and radioactive wastes and imposes penalties and sanctions for violations.

The bill, however, fell short of addressing the subject matter of e-waste in a clear and specific manner. The most recent policy crafted for e-waste management in the country is Senate Bill No. 751, known as An Act Regulating the Disposal of Electronic Equipment at Solid Waste Management Facilities and Requiring the Establishment of Recovery and Collection Facilities, filed in 2022. This policy, which is pending in the Committee of Environment, Natural Resources, and Climate Change as of July 2022, takes into account the hazards of the inappropriate disposal of electronic devices, fosters responsible manufacturing and distribution, and provides assistance to consumers in proper disposal and recycling of obsolete/discarded electronics. To give a stronger command of the existing regulations, the DENR will issue Technical Guidelines on the Environmentally Sound Management of WEEE. This proposed DAO aims to establish a comprehensive framework for e-waste management, with the following objectives: i) Reduce the volume of electrical and electronic products and mitigate associated hazards. ii) Promote the reuse of secondhand electronics and the valorization of waste elements. iii) Engage stakeholders and relevant agencies in the lifecycle of electrical and electronic equipment (EEE). iv) Institutionalize the concept of "extended producer responsibility (EPR)", assigning manufacturers the duty to collect, recycle, and dispose of their products. This approach incentivizes eco-friendly design and facilitates repair or recycling [21], [34].

It goes to show that a single instrument may not be enough to implement effective policies to combat the dilemma of e-waste. EPR, for example, has been suggested as one of the best ways to manage e-waste, and it can be legislated and implemented in the Philippines. This policy needs the involvement of various stakeholders from the local government, non-government entities, and the private sector. With reference to the policy recommendation of ITU (2021) [25], potential entry points for engagement of the government include i) preparation of local laws for sound management of e-waste and ii) establishment of proper collection facilities and local drop-off points for discarded electronics within local communities. The key roles of non-governmental groups such as academe, non-government organizations, and consumers include: i) conduct capacity building and transfer of best practices for e-waste management; ii) perform local and national research to ensure that policy decisions are taken through science-based approach; iii) create linkage to facilitate sharing of best practices; iv) support entrepreneurs, small and medium-sized enterprises intending to establish e-waste management businesses; v) compliance to laws on the bring-back of e-waste and ensure that e-wastes are only discarded to formal facilities; and vi) practice reuse or repair of electronics before bringing back for recycling and final disposal. For the private sector, such as brand manufacturers, dealers, importers, distributors, retailers, collectors, repairers and recyclers, central responsibilities include: i) ensure registration to relevant authority; ii) foster awareness about responsible disposition of e-waste; iii) provide accessible and free drop-off points of e-waste for consumers; iv) support and assist in the development of EPR regulation and establishing of fees for the EPR system; and v) observe regulations on environmental permitting and impact assessment.

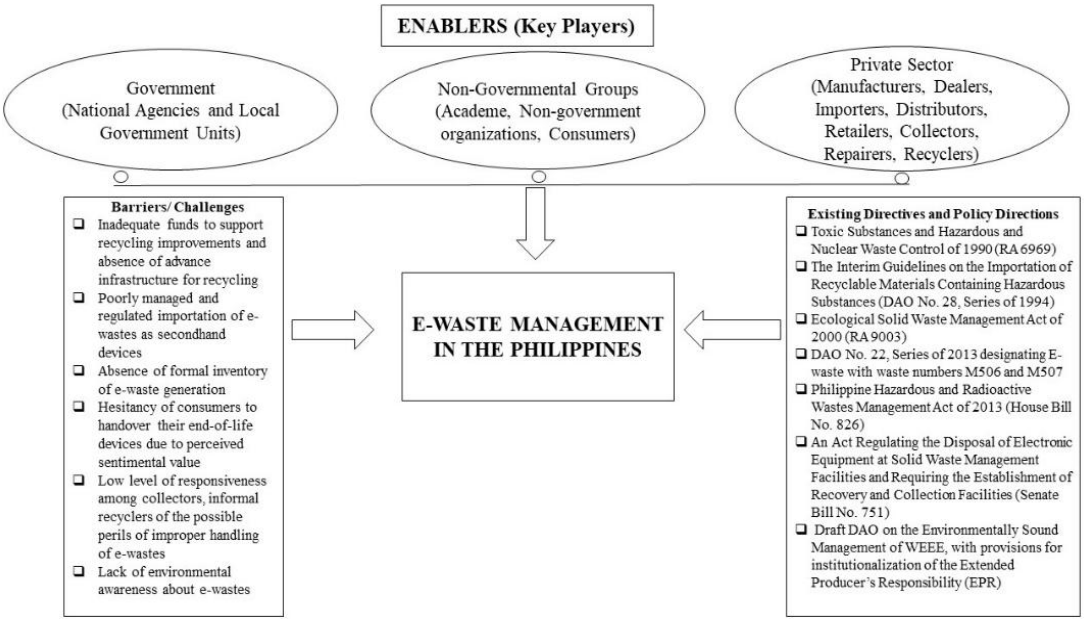

Figure 2. Framework on policy recommendation for e-waste management in the Philippines

4. CONCLUSION

New products are constantly being added to the market, and existing technology is quickly becoming obsolete due to the ICT industry's rapid evolution. While innovations have certainly made life more convenient, the advent of information technology has also brought with it an upsurge in the amount of solid waste, particularly e-waste. The problem of e-waste is gaining impetus both in the national and international arena, owing to the multiple issues linked to it, such as its rising volume, the toxic design that may pose health hazards, and the absence of monetary incentives to recycle it. The fundamental challenge, however, is the absence of specific and clear-cut regulations for e-waste. Against this background, the present work makes a modest contribution to recycling methods that can be applied to e-waste generated by educational institutions. A framework for e-waste disposal was developed to recycle ICT and electronic equipment that is beyond repair to advance knowledge on e-waste management in the Philippines. The results reveal that the discarded EEE can be turned into innovative products that can be useful both in serving their new purposes and in reducing the e-waste problems faced by HEIs. The evaluation of the e-waste recycling strategy in higher education institutions shows significant advancements in sustainable innovation. The interventions developed in the present study will set an example for community accountability on social and environmental issues. To lessen the environmental impact of electronic waste, the paper underscores the need to reinforce existing regulations through a comprehensive and effective e-waste management plan that encourages the engagement and shared accountability of various stakeholders and key players from the government, non-government, and private sectors.

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