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Review Article

Waste Electrical and Electronic Equiment (WEEE) management and policy frameworks in the Philippines: A mini review

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ABSTRACT

In 2022, the Philippines generated approximately 537,000 metric tons of Waste Electrical and Electronic Equipment (WEEE), equivalent to 4.7kg per capita, positioning the country among the top e-waste producers in Southeast Asia. This surge is attributed to rapid urbanization, increased consumer demand for electronics, and shorter product life spans. Despite existing policies like the Ecological Solid Waste Management Act (RA 9003) and the Toxic Substances and Hazardous and Nuclear Waste Control Act (RA 6969), enforcement remains inconsistent, leading to widespread informal recycling practices that pose significant health and environmental risks. This study employed a qualitative and descriptive review method to analyze academic literature, government reports, and international policy benchmarks in assessing the current state of e-waste management in the Philippines. Findings reveal that while 91 Treatment, Storage, and Disposal (TSD) facilities were registered as of 2023, their uneven distribution and the lack of infrastructure in many areas hinder effective waste management. Moreover, the continued importation of secondhand electronics further aggravates the e-waste burden. The study concludes that existing efforts are insufficient to address the growing problem and recommends the

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the enactment of a comprehensive e-waste management law, the prohibition of secondhand electronics importation for disposal, the nationwide expansion of TSD facilities, the development of a centralized e-waste collection system, and the implementation of public education and awareness campaigns.

Keywords: E-waste, Philippines, TSD Facilities, Informal Recycling, Sustainable

INTRODUCTION

The global demand and consumption of electronics have surged due to people's high reliance on maintaining a comfortable and convenient lifestyle (Aryan & Kumar, 2020). According to Global E-Waste Monitor, an estimated 62 million metric tons of e-waste were generated in 2022. It is expected that these will surpass 82 million metric tons in 2030, and that a part of these is hazardous waste. The amounts of hazardous substances per appliance are not large, but the total amount is significant. This underscores the urgency for an effective e-waste management system for developing countries like the Philippines. In these regions, a considerable amount of the world's electronic waste is relocated for disassembly and recycling, often in unsafe environments.

Waste from electrical and electronic equipment (WEEE) is one of the priority waste streams in EU waste management policy because of its significant challenges. This includes the consequences of growing quantities of waste and WEEE's complexity. It is one of the most complex waste streams because of the wide variety of products, from mechanical devices to highly integrated systems and accelerating technological innovations (European Environment Agency [EEA], 2003.)

The surge in WEEE generation in the Philippines is driven by rapid urbanization, increased consumer demand for electronics, and shorter product lifespans. Despite the existence of national policies, such as the Ecological Solid Waste Management Act and the Extended Producer Responsibility (EPR) approach, enforcement remains inconsistent. The country faces multiple challenges, including limited recycling facilities, weak policy implementation, and a highly active informal recycling sector. This has resulted in widespread informal recycling activities, often involving improper handling and disposal, exposing workers and communities to toxic chemicals.

Despite the increasing significance of this issue, a critical research gap exists in the Philippine setting, where there is a limited body of academic work that evaluates the effectiveness, coordination, and enforcement of the country's existing WEEE management policies. Moreover, few studies offer comprehensive analyses of how these policies compare to global best practices or address the structural challenges in WEEE handling and disposal.

This paper aims to present and document the current Waste electrical and electronic equipment (WEEE) management practices in the Philippines to review the current status of the management of WEEE, identify mechanisms in the collection, treatment, and disposal of WEEE, discuss regulatory efforts or policy frameworks that are intended to protect vulnerable populations from inappropriate WEEE management practices, and finally to propose a mechanism in the management of e-waste in the Philippines. This study adopts a qualitative and

descriptive review method, utilizing existing academic literature, official government reports, and international policy benchmarks to provide a contextualized analysis of the Philippines evolving approach to e-waste management.

MATERIALS AND METHODS

Electrical and Electronic Equipment

Electrical and electronic equipment (EEE) refers to any device that relies on electrical currents or electromagnetic fields to operate and fulfill its intended purpose (Shittu et al., 2020). These devices are used for data processing, telecommunications, or entertainment in homes and businesses, such as computers, entertainment systems, and mobile phones. Globally, the production of EEE is on the rise. Ongoing technological advancements and expanding markets are driving faster equipment turnover, resulting in a substantial growth in EEE devices (Tam, 2011).

The consumption of EEE, in general, has also shown rapid growth from 2000 to 2016, particularly in emerging economies with low Purchasing Power Parity (PPP). Countries with the highest PPP recorded an average growth of 1.6% per year, while those with high PPP experienced a slightly faster rate at 5.2%. In contrast, countries with mid-level PPP showed a much steeper increase, averaging 13% annually. Notably, countries with low-PPP shows the fastest growth, which reached an average of 23% per year. Meanwhile, countries with the lowest PPP still exhibited considerable growth, averaging 15% annually (UNU, 2017). As the use of EEE continues to expand globally, it is crucial to recognize that these products contain a wide range of substances that can pose serious environmental and health risks. Therefore, proper management of Waste Electrical and Electronic Equipment (WEEE) is essential to mitigate these potential harms (EU, 2006).

Waste Electrical and Electronic Equipment

When electrical and electronic products end their useful life, they become waste electrical and electronic equipment (WEEE), often referred to as electronic waste (or e-waste for short). Waste electrical and electronic streams encompass various electrical and electronic waste products, including home appliances, information technology and telecommunication equipment, consumer electronic devices, and other household electrical and electronic equipment (Jang, 2010).

According to the European Union (EU) WEEE directive, WEEE is specifically defined as electrical and electronic equipment that consumers dispose of or are required to dispose of under the provisions of national law, including all components, subassemblies, and consumables.

Balde et al. (2015) divided the electronic waste into six distinct categories:

1. Temperature exchange equipment: refrigerators, freezers, air conditioner, heat pump.
2. Screens and monitors: televisions, monitors, laptops, notebooks, tablets.
3. Lamps: fluorescent lamps, LED lamps, high-intensity discharge lamps.

4. Large equipment: washing machines, clothes dryers, electrics troves, large printing machines, copying machines, photovoltaic panels.
5. Small equipment: vacuum cleaners, toasters, microwaves, ventilation equipment, scales, calculators, radio, electric shavers, kettles, camera, toys, electronic tools, medical devices, small monitoring and control equipment.
6. Small IT and telecommunication equipment: mobile phones, PS, pocket calculators, routers, personal computers, printers, telephones.

Waste Electrical and Electronic Equipment (WEEE) is increasingly recognized as both a growing environmental challenge and a potential economic opportunity, due to the large volumes of e-waste produced and the presence of both hazardous substances and valuable recoverable materials (Widmer et al., 2005). WEEE can lead to environmental issues because it contains hazardous materials that pose serious risks to both human health and ecosystems. While WEEE waste holds value as a potential source of secondary raw materials, it becomes harmful when mishandled or improperly disposed of (Tam, 2011).

According to Balde et al. (2017), worldwide WEEE constitutes one of the fastest-growing waste fractions generated, accounting for 8% of all municipal waste. The estimated total e-waste produced worldwide was 62 million metric tons in 2022 and is expected to rise to approximately 82 million metric tons by 2030 (Statista, 2025). A major concern arising in this context is the safe disposal of Waste Electrical and Electronic Equipment (WEEE) in developing countries, an issue that has been growing since the introduction of electronic products, particularly computers. Common disposal practices, such as landfilling, incineration, or exporting e-waste to less developed nations for processing, are unsustainable and do not offer long-term solutions (Khan et al., 2014).

Effects of Waste Electrical and Electronic Equipment in the Environment

WEEE should not be combined with unsorted municipal waste destined for landfills because electronic waste can contain more than 1000 different substances, many of which are toxic, such as lead, mercury, arsenic, cadmium, selenium, and hexavalent chromium (Babu et al., 2007). The disposal of WEEE with the rest of the municipal solid Waste (MSW) stream in a landfill may result in negative impacts on the environment, e.g., groundwater contamination by lead leaching and high concentrations of lead in landfill leachate (Jang, 2010).

The open burning of plastics, widespread general dumping, exposure to toxic solders, and other malpractices associated with improper dismantling and treatment of WEEE, as observed in various developing countries, can have serious health consequences (Mureithi & Waema, 2008). When WEEE is burnt in incinerators, toxic organic contaminants such as dioxins and furans may be formed during incineration and exit through the stack to the surrounding area in the form of gaseous pollutants since most of the plastic materials in WEEE contain flame retardants that are mainly halogenated organic chemicals.

Global Approaches and Innovative Solutions in WEEE Management

According to Achillas et al. (2010), environmentally sound end-of-life management of Electrical and Electronic Equipment has been realized as a top

priority issue internationally due to the stream's continuously increasing quantities and its content of valuable and hazardous materials. Developing effective global strategies for managing Waste Electrical and Electronic Equipment (WEEE) remains highly challenging. Approaches to WEEE management differ significantly across regions, reflecting a wide range of practices and systems. The movement and flow of WEEE are often complex and difficult to trace, with many instances of unaccounted or informal waste streams. Despite this complexity, Shittu et al (2020) have identified and categorized four common management scenarios.

Scenario 1 refers to WEEE that is formally documented and collected in compliance with existing laws and regulations related to e-waste management. In this setup, WEEE is typically gathered through municipal drop-off centers, take-back programs run by EEE producers and retailers, or designated collection services. The collected items are then transported to specialized treatment facilities, where they undergo processes such as manual disassembly, shredding, and material recovery. These procedures are conducted under regulated conditions to ensure environmentally sound management (ESM).

Scenario 2 is defined by the disposal of WEEE mixed with general household waste. In this case, consumers discard electronic items without separating them from regular domestic garbage. This unsorted waste is typically sent to landfills or incinerators, depending on the common waste disposal practices in the area.

Scenario 3 involves the informal collection of WEEE, often carried out by independent waste brokers or dealers. The collected items may be recycled at specialized facilities, refurbished, or exported—frequently to developing countries. Unlike in Scenario 1, this process operates outside official documentation, making it difficult to monitor or quantify the amount of WEEE collected and processed. This lack of oversight is often due to the absence of legal frameworks or enforcement mechanisms for e-waste management. As a result, the treatment of WEEE under this scenario may not follow environmentally sound practices, and in some cases, may lead to illegal export activities.

Scenario 4 is commonly observed in developing countries and involves the informal collection of WEEE directly from consumers by waste brokers or scrap collectors. These activities are typically unregulated due to the lack or weak enforcement of WEEE-related legislation. As a result, the methods used for treating e-waste are often crude and hazardous, with metal recovery commonly performed through open burning or acid leaching. This scenario also includes the reuse, repair, and salvaging of WEEE components for parts. While more prevalent in low-income regions, similar informal practices can also be found in parts of Europe.

Moreover, various regions have implemented regulatory frameworks to address this issue. One prominent example is the European Union's Directive 2002/96/EC, which significantly raised recycling targets and emphasized the recovery of materials and energy from WEEE. This directive was originally introduced under the principle of extended producer responsibility (EPR), requiring manufacturers and importers of electrical and electronic equipment to collect used and discarded products from consumers and ensure their proper environmental treatment. At the time of its adoption, the directive set a minimum collection goal of

4kg per person per year. However, its implementation posed considerable challenges for EU Member States, particularly in establishing the necessary legal and technical infrastructure for collection and processing. To improve the system, the directive was revised in 2012, clarifying its scope and introducing new collection targets based on the amount of WEEE generated in each country. This updated version officially replaced the original directive in 2014. Starting in 2016, Member States were required to collect at least 45% of the average weight of EEE placed on the market over the previous three years. By 2019, the collection target increased to 65% of the average EEE placed on the market or 85% of the WEEE generated annually within each country (Shittu et al., 2020).

Building on such regulatory initiatives, research institutions and industry stakeholders have begun developing and testing more efficient recycling technologies to meet these growing demands. A notable example comes from the Helsinki University of Technology, where collaboration between the laboratories of Energy Engineering, Environmental Protection, and Mechanical Process Technology has led to innovative methods that combine mechanical and thermal recycling techniques.

Several case studies illustrate the potential of these integrated approaches. In one instance, the pyrolysis of low-grade, organic-bearing circuit boards enabled the recovery of non-ferrous metals. Another example demonstrated how combining the recycling of old refrigerators with the incineration of chlorofluorocarbons compounds significantly reduced energy use. A third case explored the treatment of high polyvinyl chloride content waste, focusing on chlorine recovery and minimizing corrosion risks in furnaces. These examples highlight how technical innovation, aligned with policy goals, can support more sustainable and efficient WEEE management.

The Philippines and WEEE

The Philippines is a traditional importer and exporter of electrical and electronic equipment (EEE), both new and used, including scraps. With the rapid global technological advances for commercial, industrial, and household products and appliances, there is a corollary increase in Waste Electrical and Electronic Equipment (WEEE) and hazardous substances from the source materials involved in their manufacture and use (EMB, 2016). According to Aoki (2020), WEEE generation in the Philippines has been on the rise, reaching a total of 32,664.41 tons in 2019. Additionally, a study conducted by the International Telecommunication Union, United Nations University, and the International Solid Waste Association highlighted the increasing levels of WEEE globally. The report revealed that in 2017, each person in the Philippines generated approximately 2 to 5kg of e-waste.

WEEE management typically involves activities carried out by both the formal and informal sectors. Formal facilities are officially recognized businesses that handle large volumes of used electronics from contracted clients and operate in accordance with environmental standards. These facilities process various types of waste, including plastics, traditional electronic waste like CRT monitors, refrigerators, circuit boards, and cables, as well as newer forms such as LCD screens and solar panels. In contrast, the informal sector consists of unregulated operations with few workers. These sites mainly deal with older types of WEEE and

rely on manual labor, basic tools, and low-cost methods. The informal sector often operates outside legal frameworks, typically does not pay taxes, and avoids compliance with government policies. In developing nations such as the Philippines, the majority of WEEE recycling is conducted by this informal sector, which includes junkshops and independent collectors (Celestial et al., 2018).

Wastes from Electrical and Electronic Equipment are classified as hazardous waste under DENR DAO 2004-36 or Procedural Manual for Hazardous Waste Management and also on the updated DENR DAO 2013-22 or Revised Procedures and Standards for the Management of Hazardous Wastes. Hence, WEEE shall be covered by RA 6969 or The Toxic Substances and Hazardous and Nuclear Waste Control Act of 1990 and require a unique disposal process or system.

The Department of Environment and Natural Resources (DENR), through the Environmental Management Bureau (EMB), has developed guidelines on the environmentally sound management of WEEEs, as they recognized the risks of WEEE in part or whole to human health and the environment. The guideline provides the compliance framework for producers, manufacturers, consumers, distributors, retailers, treatment facilities, and other stakeholders involved in the life cycle of WEEEs (EMB, 2006). This is also in compliance with the country's international commitment as a signatory to the Basel Convention - an international treaty that was designed to reduce the movements of hazardous waste between nations and specifically to prevent the transfer of hazardous waste from developed to less developed countries (LDCs).

While the Philippines has established policies and engaged in initiatives to address WEEE, the effective management of WEEE still remains a complex issue both nationally and globally due to several factors. One of the main reasons e-waste remains a neglected issue is the general public's lack of awareness regarding its hazardous components and the harmful effects it can have on both health and the environment. For many people, electronic devices are simply thrown away once they are no longer usable, without considering their proper disposal. A study conducted by engineers from the University of the Philippines Department of Environmental Engineering revealed that approximately 22 million mobile phones were discarded in 2016. Additionally, a separate survey showed that 95% of respondents were unaware of the correct methods for disposing of e-waste (Mateo, 2019).

Additionally, data deficiencies further worsen the problem. There is a lack of comprehensive and reliable data on the volume and flow of e-waste within the country, which restricts the development of informed policies and targeted interventions. This data gap is partly due to the unregulated nature of the informal sector and the absence of systematic monitoring mechanisms (Temperton, 2017).

The Current Status of WEEE in the Philippines

According to the Global E-Waste Monitor 2024, the Philippines generated approximately 537 million kilograms (537,000 metric tons) of WEEE in 2022, equating to 4.7kg per capita (Ordinario, 2024). This marks a significant increase from 3.9kg per capita in 2019, highlighting a growing trend in electronic waste production. Another from 2019, "A New Circular Vision for Electronics: Time for a Global Reboot" showed that 80% of e-waste goes to a landfill or is informally recycled, while less than 20% is formally recycled (Argosino, 2022). However, there

is insufficient data regarding the actual value and extent of e-waste generation in the Philippines as there is no official inventory of the actual e-waste. Very few studies have been done regarding estimations and projection levels of e-waste generation using assumptions based on indicators like economic and population growth (Peralta & Fontanos, 2006; Alam, 2016).

The Republic Act No. 9003 of the Philippines, with the short title Ecological Solid Waste Management Act of 2000, was signed into law in January 2001. RA 9003 sets guidelines and targets for solid waste avoidance and volume reduction through source reduction and waste minimization measures, including recycling, reuse, and recovery before collection, treatment, and disposal at appropriate and environmentally sound solid waste management facilities. Under this law, consumer electronics and white goods are classified as special wastes requiring separate handling from other residential and commercial wastes (Peralta & Fontanos, 2006). The Department of Environment and Natural Resources (DENR), through the Environmental Management Bureau (EMB), has developed Guidelines on the ESM of WEEEs recognizing the risks of WEEE in part or in whole to human health and the environment (EMB, 2016).

Moreover, the Republic Act No. 6969, or the Toxic Substances and Hazardous and Nuclear Waste Control Act of 1990, regulates the importation, manufacture, processing, handling, storage, transportation, sale, distribution, use, and disposal of chemical substances and mixtures in the Philippines including the entry, even in transit, as well as the storage and disposal of hazardous and nuclear wastes into the country for whatever purpose. However, there has been an absence of a clear policy framework, RA 6969 addresses hazardous waste but does not specifically define or provide comprehensive guidelines for WEEE. This absence of targeted legislation leads to fragmented enforcement and regulatory gaps (Alegre & Borcena, 2010).

DENR Administrative Order (DAO) 28 Series of 1994, the Interim Guidelines on the Importation of Recyclable Materials Containing Hazardous Substances, allows the importation of recyclable materials, including electronic assemblies and scraps.

In the Philippines, legislative efforts have been introduced to address the growing issue of electronic waste. Senate Bill No. 568, also known as the E-Waste and Cellular Phone Recycling Act, was filed during the 17th Congress by Senator Antonio Trillanes. The bill seeks to establish legal guidelines for the collection, transportation, and recycling of electronic waste and cellular phones. Its counterpart in the House of Representatives, House Bill No. 5901 or the E-Waste Management Act, was likewise filed in the same Congress. However, both bills remain pending in their respective committees and have yet to be enacted into law (Senate of the Philippines 2016, House of Representatives of the Philippines 2017).

Generation of WEEE in the Philippines

According to Global E-Waste monitor 2024, the Philippines generated an amount of 537 million kilograms of WEEE in 2022, making it second to Indonesia having 1.886 billion kilograms of WEEE, ranking it among the top e-waste producers in Southeast Asia. In terms of per capita e-waste, the Philippines is 6th out of the 10 Asean countries, with Singapore having the highest number of 20.3kg per capita of e-waste (Ordinario 2024). With the increasing population, the market for electronic equipment will continue and is expected to increase as well.

A 2016 study titled "The Assessment of the of E-Waste Management Generated from Cellular Phones, Laptops, and Personal Computers in the Philippines" shows how Filipinos dispose of mobile phones, laptops, and personal computers. For mobile phones, the findings showed that approximately 33% of respondents kept their old devices in storage, 23% gave them to relatives or friends, 19% sold them to junk shops, 13% discarded them along with regular household waste, and only about 2% actually recycled them. When it came to laptops and personal computers, around 36% of respondents stored their outdated devices, 13% sold them to junk shops, 5% threw them away with general garbage, and 6% recycled them. The study also shows that, about 69% of respondents acknowledged the harmful effects of improper WEEE disposal on human health and the environment. However, nearly all were unaware of the final fate of their discarded electronic gadgets (Alam, 2016).

International trade also contributes to the amount of WEEE generated in the Philippines. The Department of Environment and Natural Resources (DENR) Administrative Order 2013-22 permits the importation of recyclable materials, including electronic assemblies and scrap, under specific conditions. However, this provision has been exploited, allowing e-waste to enter the country labeled as "used equipment" or "electronic accessories," making it challenging to monitor and regulate these imports effectively. In 2015, data from the Environmental Management Bureau (EMB) indicated that South Korea was a significant source of imported WEEE, sending over 215,000 used televisions or computer monitors, more than 53,000 used computers or accessories, and approximately 200 used refrigerators or air conditioning units to the Philippines. Other countries, including Japan, Singapore, Sweden, and Germany, also contributed to WEEE imports, primarily in the form of used photocopy machines (Earth Thailand, 2016).

A notable incident also occurred in May 2019 when the Bureau of Customs intercepted a shipment from Hong Kong falsely declared as "assorted electronic accessories." The shipment contained 2.56 tons of smashed electronic waste and was intended as a "test cargo," with plans for 70 more containers to follow had it not been discovered. Environmental groups have urged the Philippine government to ratify the Basel Convention Ban Amendment, which prohibits the export of hazardous waste from developed to developing countries. They also advocate for a comprehensive ban on all waste imports to prevent the country from becoming a dumping ground for foreign WEEE (De Vera-Ruiz, 2020).

Despite these concerns, the Philippines has yet to ratify the Basel Ban Amendment, leaving regulatory gaps that allow the continued importation of WEEE under the pretense of recyclables or second-hand goods.

Collection of WEEE in the Philippines

The collection of WEEE, which may be classified as "special waste" under RA 9003, is the responsibility of the municipality or city. However, there are only few DENR-accredited WEEE management facilities, most WEEE in the Philippines is handled by the informal sector, including scavengers, waste pickers, and junkshop operators. This informal handling often leads to improper recycling methods, posing environmental and health risks. Despite the Department of Environment and Natural Resources (DENR) classifying e-waste as a new class of miscellaneous waste under Administrative Order No. 2013-22, a formal and comprehensive e-waste management system is still lacking in the country (Celestial, 2020).

As of January 2023, the Philippines had 91 registered Treatment, Storage, and Disposal (TSD) facilities authorized to handle WEEE (e-waste), classified under waste code M506 by the Department of Environment and Natural Resources – Environmental Management Bureau (DENR-EMB) (BAN Toxics, 2024).

Despite this growth, the distribution of TSD facilities remains uneven, with a concentration in major urban areas. According to Agoot (2023), the DENR-EMB has initiated the conversion of Materials Recovery Facilities (MRFs) into e-waste handling centers. Notably, facilities in Barangay Bagong Silang (Caloocan), Barangay Dampalit (Malabon), and Barangay Bakakeng Central (Baguio City) have been upgraded to manage e-waste (Agoot, 2023).

However, challenges persist. A significant portion of e-waste is still processed informally, often by unregulated sectors, leading to environmental and health risks. In Quezon City, for example, approximately 30% of e-waste is recycled informally in junk shops (BAN Toxics, 2024).

Management of WEEE in the Philippines

The management of waste electrical and electronic equipment (WEEE) in the Philippines relies on a combination of formal and informal strategies for collection, recycling, and disposal, as Figure 1 shows. Despite the presence of regulatory frameworks, challenges remain due to inadequate infrastructure, informal recycling practices, and the inherent complexity of electronic waste. Moreover, no comprehensive solution has been fully implemented to address the WEEE problem. Even in first-world countries, recycling or refurbishing are the primary approaches to mitigating WEEE. Economic, environmental, public health and data security are the driving forces behind recycling e-waste (Mostafa & Sarhan, 2018).

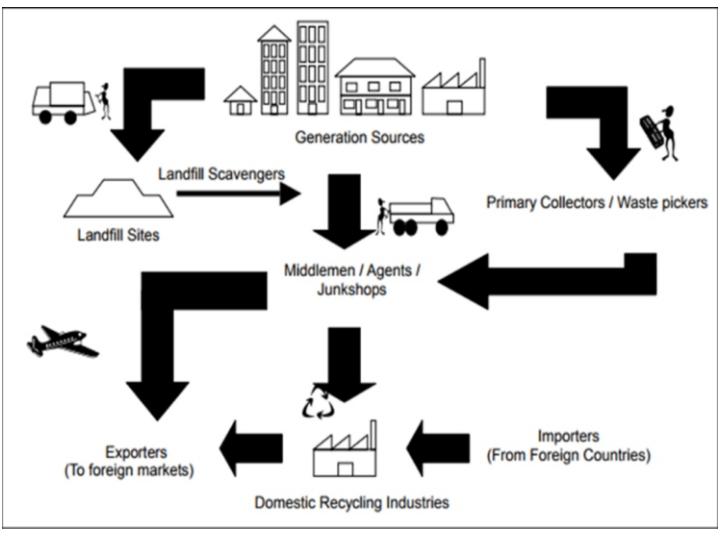

Figure 1. Current recycling activities in the Philippines

Recycling is well-known for its environmental benefits, which include resource conservation, energy conservation, and reductions in water and air pollution, including reductions in greenhouse gas generation. However, it also has significant economic and public health and safety benefits, many of which are often overlooked. Recycling is an important segment of the national economy. It creates jobs and saves money for generators of waste. If e-waste are recycled and reused, the government will not have to spend a large amount of money on mining, deforesting the flourishing lands for mining, importing minerals and buying limited fossil fuels from other countries. Instead, this money could be used where it is needed the most. As indicated earlier, e-waste contains hazardous metals and chemicals, posing threat not only to the environment but also to public health and safety. Thus, recycling through proper techniques and safer recycling facilities is important to reduce the risks of e-waste related to the environmental and public health and safety issues.

There are, however, efforts from companies to make their design of gadgets easier to recycle and recover parts of, which will help reduce the generation of WEEE. LG and Samsung, for example, have already introduced the concept of modular phones. Companies are also investing in using recyclable and green materials for electronic gadgets in their design. Eco-friendlier OLED is slowly replacing LCD, for example. OLED uses less energy and is made from organic dye, making it relatively safe to dispose of.

Proposed Mechanism in the Philippines

Collection process

The proper collection of waste is the prerequisite for the management of e-waste. The source of e-waste varies from household to office and business, and the waste composition differs depending on the generation source. The e-waste collection is usually done by the informal sector in developing nations due to a lack of legislation and take-back policies (Arora, 2008). This practice is also happening in the Philippines. Because of this, a centralized system should be implemented between junkshops and the solid waste collection department in the collection process to ensure all discarded e-waste is properly managed. Several countries have successfully implemented centralized systems for WEEE (e-waste) collection, with Germany, Japan, and Canada serving as notable examples. In Germany, the EAR Foundation (Stiftung Elektro-Altgeräte Register) manages producer registration and coordinates WEEE take-back nationwide. Japan enforces e-waste management through its Home Appliance Recycling Law, implemented by manufacturers in coordination with the Association for Electric Home Appliances (AEHA, nd). Similarly, in Canada, the Ontario Electronic Stewardship (OES) managed the province's e-waste recycling system until 2020, when responsibilities transitioned to the Resource Productivity and Recovery Authority (RPRA nd).

For the Philippines, a centralized system can be achieved by integrating the junkshop network with the solid waste collection department to facilitate the systematic collection of e-waste. WEEE brought to the Material Recovery Facility (MRF) should then be sent to a qualified Treatment, Storage, and Disposal (TSD) facility for proper processing. Furthermore, WEEE management can be enhanced

by utilizing an IoT-based e-waste collector machine, providing an innovative, efficient, and reliable e-waste disposal method, as Singh et al. (2024) discussed. This approach would improve the monitoring, efficiency, and effectiveness of the collection and recycling process, ensuring better environmental outcomes and compliance with regulations.

Methods for WEEE Management

Reuse is a key part of the e-waste solutions toolkit. It is a response to the shortening of product life spans that are leading to more significant pressure on resource extraction, increased manufacturing burdens, and the burgeoning quantities of e-waste. Reuse is the optimization of the use phase that helps alleviate or moderate the existing problems until products are utilized to a much more optimal level before being recycled in the most efficient means possible. Reuse plays a significant role in providing spare parts for long life and high-value equipment, whereas manufacturing new parts may be rather expensive. According to Kuehr et al. (2019), the renewed focus on the availability of certain critical materials further strengthens the logic for considering reuse as a part of a business strategies.

The recycling process is considered the best way to dispose of electronic components only if the process employs environmentally sound recycling (Arora, 2008). The depolymerization and conversion process is the chemical recycling of plastics, which has several developed processes. One of these processes was developed by the Association of Plastics Manufacturers in Europe (Association of Plastics Manufacturers in Europe, 2007). Metals are removed for processing. The remaining polymer chains from the depolymerization unit are cracked at about 350–450°C temperatures in the Hydrogenation Unit. The open carbon bonds are saturated by hydrogen because of high hydrogen pressure, more than 10 million N/m2 (Association of Plastics Manufacturers in Europe, 2007). The liquid product goes through the distillation process. Any leftover inert material is not separated and removed in the depolymerization step. The unconverted plastic portion is collected at the bottom of the distillation column and removed as a residue, hydrogenation bitumen. The final high-quality products, off-gas, and sync, are rude and are obtained by hydro treatment. These final products are then sent to a conventional petrochemical process (Tam, 2011). This form of recycling is helpful in treating emerging e-waste in the Philippines.

According to Yoshida et al. (2010), China, Indonesia, and Vietnam have already banned the importation of secondhand electrical and electronic equipment (EEE). These bans are driven by concerns that secondhand EEE generally has a short life span and must soon be disposed of or recycled. Importing such equipment not only adds to a country's existing WEEE burden but also poses significant environmental and public health risks. Given these concerns, bans on the importation of secondhand EEE, alongside reuse and recycling strategies should also be considered in e-waste management policies.

According to Neighboring De Vera-Ruiz (2020), neighboring countries like Thailand have taken proactive steps by implementing bans on the importation of certain types of electronic waste. Thailand's policy prohibits the entry of 428 types of electric and electronic components and scraps, with violators facing severe penalties.

The Philippines continues to allow the importation of secondhand electrical and electronic equipment (EEE), including used air conditioners and other appliances. While the Department of Environment and Natural Resources (DENR) requires importers to secure permits and clearances for such imports, the sector remains largely unregulated, with no comprehensive framework to ensure the safe reuse, repair, or recycling of these items. This regulatory gap contributes to environmental and public health risks associated with the improper handling of hazardous materials found in e-waste.

Disposal

E-waste disposal strategies remain a significant concern, as various e-waste operations are highly polluting and can harm human health. Examples include the dumping of acids into rivers and the widespread, indiscriminate disposal of e-waste.

Currently, and unfortunately, most of the e-waste ends up in landfills. Landfills remain the most economical and convenient method of waste disposal worldwide. B. Seshadri et al. (2016) claim that in many developed and developing countries, domestic and industrial waste is primarily managed through landfilling. Thus, the proposed disposal method involves the use of a sanitary landfill. The sanitary landfill should be well-engineered and designed to comply with the guidelines outlined in RA 9003, ensuring an effective and environmentally sound landfill system is established. 9003 on how to establish an effective landfill.

CONCLUSION

The growing generation of WEEE in the Philippines shows the urgent need for a more effective and sustainable management system. Rapid urbanization, technological consumption, and limited infrastructure have accelerated e-waste generation. While existing laws such as the Ecological Solid Waste Management Act (RA 9003) and the Toxic Substances and Hazardous and Nuclear Waste Control Act (RA 6969) provide general frameworks, they fall short in specifically addressing the unique challenges of e-waste. The informal sector continues to dominate WEEE collection and processing, often engaging in unsafe and environmentally damaging methods. Despite the establishment of Treatment, Storage, and Disposal (TSD) facilities and the initiation WEEE handling centers, the country still lacks a unified and centralized strategy. Moreover, the continued importation of secondhand electronics under weak regulatory worsens the problem.

While efforts such as DENR's guidelines and the conversion of MRFs into e-waste centers mark positive developments, gaps in enforcement, public participation, and centralized collection persist. A more integrated and inclusive approach leveraging formal recycling, innovative technologies like IoT-based collection systems, and global best practices must be adopted. Furthermore, legislation specific to WEEE, bans on hazardous imports, and stronger public-private partnerships are essential to protect both environmental and human health.

RECOMMENDATION

To effectively address the growing challenges of e-waste management in the Philippines, the following policy recommendations are proposed to enhance regulation, infrastructure, and public engagement:

1. Enact a Comprehensive E-Waste Management Law
2. Ban the Importation of Secondhand Electronics for Disposal
3. Strengthen and Expand TSD Facilities Nationwide
4. Implement a Centralized E-Waste Collection System
5. Public Awareness and Education Campaigns

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AVAILABILITY OF DATA AND MATERIALS

The data were derived from the literature study; no primary data was produced. So, the data is not shared.

ETHICAL CONSIDERATIONS

This article did not include human subjects or animal studies.

COMPETING INTEREST

The authors declare no conflict of interest.

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