

Domestic Challenges and Transboundary Linkages in Environmentally Sound E-waste Treatment in Emerging Economies Cases from Four Selected ASEAN Member States

Reo Hirata

Fusanori Iwasaki

Reo Kawamura

Kyoto Working Papers on Area Studies No. 141

May 2026

Kyoto Working Papers on Area Studies is a series published jointly by the three area studies institutions on Kyoto University campus: the Center for Southeast Asian Studies (CSEAS); the Graduate School of Asian and African Area Studies (ASAFAS); and the Center for African Area Studies (CAAS).

The papers are also available on our website:

(Japanese)

<https://edit.cseas.kyoto-u.ac.jp/ja/kyoto-working-papers-on-area-studies/>

(English)

<https://edit.cseas.kyoto-u.ac.jp/kyoto-working-papers-on-area-studies/>

“Domestic Challenges and Transboundary Linkages in Environmentally Sound E-waste Treatment
in Emerging Economies: Cases from Four Selected ASEAN Member States”
May 2026

Center for Southeast Asian Studies
Kyoto University
46 Shimoadachi-cho,
Yoshida, Sakyo-ku,
Kyoto 606-8501, JAPAN
Tel: +81-75-753-7302

©2026

Center for Southeast Asian Studies (CSEAS)
Graduate School of Asian and African Area Studies (ASAFAS)
Center for African Area Studies (CAAS)
All rights reserved

The opinions expressed in this paper are those of the authors and do not necessarily reflect
the views of CSEAS, ASAFAS, and CAAS.

**Domestic Challenges and Transboundary Linkages in Environmentally
Sound E-waste Treatment in Emerging Economies
Cases from Four Selected ASEAN Member States**

**Reo Hirata
Fusanori Iwasaki
Reo Kawamura**

Kyoto Working Papers on Area Studies No. 141

May 2026

Domestic Challenges and Transboundary Linkages in Environmentally Sound E-waste Treatment in Emerging Economies Cases from Four Selected ASEAN Member States *

Reo Hirata **, Fusanori Iwasaki *** and Reo Kawamura ****

1. Introduction

As the global digital transformation continues to flourish, the issue of Electrical and Electronic Equipment (EEE) Waste (e-waste) management has become a key challenge in achieving a circular economy. Indeed, Baldé et al. (2024) demonstrate the rapid global increase in e-waste: for instance, 62 million tonnes of e-waste were generated worldwide in 2022, and this figure is projected to rise to 82 million tonnes by 2030. Despite the growing volume of e-waste, only 22.3% of e-waste was documented as formally collected and recycled in 2022. Under a business-as-usual scenario, this rate is expected to fall to 20% by 2030.

Scholarly attention to e-waste management has also expanded rapidly. According to the “Web of Science”, which is one of the trustworthy and largest academic online database platforms in the world, the number of published articles including “e-waste” into their titles has rapidly increased in the past decade. For example, the annual number of such articles rose from 260 in 2015 to 861 in 2025. Cumulatively, the total number of publications increased from 1,423 up to 2015 to 7,236 up to 2025.

This growing attention reflects the scale and urgency of the challenge, but it also highlights how uneven policy and insufficient infrastructure remain across regions. These

* Note regarding the whole paper is a pre-review manuscript currently under submission to “Waste Management & Research”, Sage Publishing. This study provides some research results by the ERIA’s research project, “Research on Sound International Resource Circulation in ASEAN Region” which was financially supported by the Ministry of the Environment, Japan (MOEJ). The full report of the project is undergoing editorial check in ERIA Publishing and is subject to release within 2026. The views expressed in the paper are solely those of the authors, and do not necessarily represent those of the organizations with which the authors are affiliated, ERIA and MOEJ.

** Lecturer, Faculty of Economics and Business, Saitama Gakuen University, Saitama, Japan (1510 Kizoro, Kawaguchi, Saitama, 333-0831, Japan) and Affiliated Lecturer, Center for Southeast Asia Studies, Kyoto University, Kyoto, Japan. (46 Shimoadachi-cho, Yoshida, Sakyo-ku, Kyoto 606-8501, Japan)
E-mail: hirata.reo.f52@kyoto-u.jp

*** Research Fellow, Economic Research Institute for ASEAN and East Asia (ERIA), Jakarta, Indonesia. (Sentral Senayan II, 5th, 6th & 15th Floors, Jalan Asia Afrika No.8, Gelora Bung Karno, Senayan Jakarta Pusat 10270, Indonesia)

Corresponding author’s E-mail: fusanori.iwasaki@eria.org

**** Director for Environmental Policy, Economic Research Institute for ASEAN and East Asia (ERIA), Jakarta, Indonesia.

problems are much more severe in emerging economies such as Association of Southeast Asian Nations (ASEAN) member states where rapid economic growth, rising incomes, population increase, and expanding markets have not been matched by adequate formal collection and treatment infrastructure. For instance, the annual average of formal collection and recycling rate exceeded 40 percent in Europe and in Oceania, whereas it was only 11.8 percent in Asia (Baldé et al., 2024). As a result, informal collection and recycling often play a substantial role, creating persistent barriers to environmentally sound treatment and material recovery.

Compared to developed countries, e-waste management in these economies poses more complex policy challenges because weak regulatory and infrastructure capacities coexist with deeply embedded informal collection, dismantling, and recycling systems. Previous studies on e-waste management have primarily focused on the absence of infrastructure and legislative frameworks for appropriate management in developing countries (Osibanjo & Nnorom, 2007), as well as the socioeconomic, health, and environmental impacts by informal sectors, and the need to integrate informal sectors into more regulated systems (Ezeah et al., 2013; Widmer et al., 2005).

While existing studies have documented the legal and institutional weaknesses of e-waste management in developing economies, as well as the persistent role of informal sectors, these issues have often been examined separately. Moreover, while the literature increasingly acknowledges the importance of global and regional value chains, it has focused mainly either on strengthening regulation against illegal cross-border movements or on the technical and regulatory shortcomings of domestic systems. Overall, previous research has paid less attention to how weak domestic collection systems, uneven formal treatment capacity, and transboundary downstream linkages interact to shape actual pathways toward environmentally sound e-waste management. As a result, the conditions under which household e-waste can be captured into traceable formal channels remain insufficiently understood. This gap is especially important in contexts where formal treatment facilities exist to some extent, but substantial e-waste flows continue to be handled through informal or weakly regulated channels. We therefore examine the following research questions: (1) what pathways toward environmentally sound e-waste treatment are shared across the four countries, and (2) what critical factors enable the realization of these pathways?

To fill this research gap and to answer the research questions, this study focuses on how domestic governance capacity, material flows, and transboundary linkages jointly shape the emergence of environmentally sound e-waste management in four selected ASEAN member states: Malaysia, the Philippines, Thailand and Viet Nam. According to Baldé et

al. (2024), these countries differ markedly in e-waste generation intensity, for instance, 12.2kg e-waste per capita generated in Malaysia, but 4.7kg in the Philippines (Details are provided in Table 1). At the same time, they also differ in the structure of household e-waste collection, the role of informal sectors, the territorial distribution of treatment facilities, and the conditions under which domestic systems are connected to transboundary downstream recovery. Against this background, the four countries are suitable for comparative country studies on how environmentally sound e-waste management may be enabled under different institutional and market conditions.

This study adopts a comparative case-study approach, drawing on policy and legal reviews, available statistics on e-waste generation and documented collection, recycling, indicators of treatment capacity, and trade-related information, complemented by existing reports and stakeholder insights where available.

This paper contributes in two ways. First, it clarifies the conditions under which more environmentally sound e-waste management may emerge in the contexts of the emerging countries by examining the interaction of domestic collection systems, formal treatment capacity, informal-sector dynamics, and transboundary downstream linkages. Second, it identifies the main bottlenecks that hinder the formalization of household e-waste flows and points to practical levers for strengthening collection systems, traceability, institutional coordination, and cooperation between informal sectors and licensed facilities.

This paper consists of six sections. Following this introductory section, Section 2 overviews the current situation of e-waste disposal and management in the selected countries and reviews the previous literature. Section 3 outlines the dataset and analytical approach used for the comparative country studies. Section 4 presents the research findings from the country studies, Section 5 discusses the results and policy implications, and Section 6 concludes with the key contributions and limitations of this discussion paper.

2. Background and Literature Review

2.1 Definition and scope of e-waste

This section clarifies the scope of e-waste by drawing on the widely used categorization provided in Annex IV of Directive 2012/19/EU (2012). In this Annex, e-waste has six categories; (1) Temperature exchange equipment, (2) Screens, monitors, and equipment containing screens having a surface greater than 100 cm², (3) Lamps, (4) Large equipment, (5) Small equipment, and (6) Small IT and telecommunication equipment (no external dimension more than 50 cm). Appendix 1 summarizes the non-exhaustive list of e-waste

under the above six categories.

2.2 E-waste challenges in selected ASEAN member states

According to Baldé et al. (2024), the current situation of e-waste generation per capita in selected four ASEAN Member States is diverse. Table 1 shows that the amount of e-waste generation (million kg and kg per capita)¹. The amount of e-waste generation (million kg) in Thailand is the largest among the countries, followed by the Philippines, Viet Nam and Malaysia. A comparison between Thailand, which has the highest volume of e-waste generation, and Malaysia, which has the lowest, indicates that Thailand generates approximately 1.8 times as much e-waste as Malaysia. However, Malaysia, where the amount of e-waste generation is lowest among target countries, records the highest e-waste generation per capita. Malaysia and Thailand also record higher per capita e-waste generation than the Philippines and Viet Nam. In this way, the situation within ASEAN member states is diverse, but in general, the expansion of the e-waste generation is anticipated along with economic growth.

Table 1: Status quo of e-waste generation in selected four ASEAN Member States, Asia and the world in 2022

Country or Region	E-waste generated (million kg)	E-waste generated (kg per capita)
Malaysia	411	12.2
Philippines	537	4.7
Thailand	753	10.5
Viet Nam	516	5.3
Asia	30,000	6.4
World	62,000	7.8

Source: Baldé et al. (2024)

2.3 Literature review

The management of e-waste in developing economies is characterized by significant structural and regulatory hurdles, the prevalence of informal recycling systems, and complex transboundary flows. Several studies have reported the challenges to manage e-waste in developing countries, and this review organizes those contributions into three thematic areas: (1) institutional and regulatory weaknesses, (2) the informal sector, and (3) transboundary e-waste movements.

2.3.1 Institutional and Regulatory Weaknesses in Developing Economies

¹ The detailed calculation formula and steps are described in Baldé et al. (2024, pp. 110-111).

Early studies consistently emphasize the lack of adequate institutions and technologies for environmentally sound e-waste management. For example, Osibanjo and Nnorom (2007) argued that there are three major challenges in developing countries: the inadequate waste management, the absence of legislation dealing specifically with e-waste, and the lack of frameworks for end-of-life product take-back or implementation of extended producer responsibility (EPR). Andeobu et al. (2021) conduct a systematic review of major e-waste producing countries in Asia-Pacific region, providing that the two most fundamental barriers are the lack of efficient collection and recycling systems and the absence of mechanisms to hold producers accountable for end-of-life disposal. Additionally, some studies show that these challenges are intensified by rapid market growth, weak regulation, and the prevalence of informal recycling systems. Widmer et al. (2005) note that the countries with large populations such as China and India have generated large volumes of e-waste even though per-capita e-waste generation remains relatively low. Moreover, these countries are among the rapidly growing markets for the electrical and electronic equipment, implying a further increase in the future e-waste generation. They also argue that emerging economies often receive imported e-waste disguised as second-hand goods, while weak regulatory systems allow environmentally harmful but profitable informal recycling practices to flourish. At the global level, only 78 countries have any e-waste legislation in place (Shahabuddin et al., 2023), underscoring the breadth of the governance gap.

2.3.2 The Informal Sector

A substantial strand of literature highlights the central role of the informal sector in e-waste management in developing economies, in particular. Ezeah et al. (2013) argue that the effective integration of the informal sector into recycling systems is essential, and identify six crucial aspects: social acceptance, political will, mobilization of cooperatives, partnerships with private enterprises, management and technical skills, and legal protection measures. Akenji et al. (2011) highlight that in developing Asia the informal waste sector actively competes with formal EPR systems, and that the mismatch between comprehensive EPR schemes and the limited institutional capacity of developing economies makes full EPR implementation unlikely without a gradual phased approach. These studies suggest that the informal sector should not be treated merely as an obstacle to formalization, but as an embedded component of existing collection and dismantling systems. The policy challenge is therefore not only to eliminate informal practices, but also to design institutional arrangements through which informal sectors can be progressively connected to formal and traceable recycling channels.

2.3.3 Transboundary E-Waste Movements

Another important strand of literature focuses on international e-waste flows. Liu et al. (2023) discuss that e-waste from high-income countries is routinely transferred to low- and middle-income countries for informal recycling, with workers employing crude recovery methods that produce negative and irreversible impacts on local, regional, and global ecosystems. Awasthi and Li (2017), in their comparative review of China and India, highlight that informal collection systems and primitive processing dominate e-waste management, and that mislabelling leads to illegal transboundary movement; they propose restrictions on illegal cross-border movements and support for formal, regulated recycling industries through incentives and infrastructure investment, emphasizing the combination of local pre-processing with high-standard end-processing at the global level. Shinkuma and Nguyen Thi Minh (2009) examined the movements of the second-hand products and e-waste scrap, particularly printed circuit boards, among Japan, China, Viet Nam and Cambodia, and proposed alternative recycling systems, including subsidies for proper recycling and mechanisms to maintain traceability. More recently, Neves et al. (2024) analyzed the effect of EU regulations on e-waste. Their study proposes that environmental taxation itself does not necessarily reduce export flows. In some cases, taxation on manufacturers may even increase them. Their findings also show that export dependence and inadequate domestic collection systems contribute to the continued exportation of e-waste.

While previous studies have generated important insights into institutional weaknesses, the informal sector, and transboundary e-waste flows, these strands of research remain fragmented. Less attention has been paid to how these factors work in specific national contexts or how domestic collection and pre-processing systems can be linked to international downstream recovery networks. Moreover, previous research on transboundary e-waste flow has focused on restricting illegal cross-border movements, with less attention to the question of how regulated export linkages might complement domestic e-waste management.

In response to these gaps, this study examines e-waste management across four ASEAN member states through an integrated framework that links domestic collection systems, institutional coordination, and dynamics of informal sectors, and transboundary downstream recovery networks. It examines how they connect, or could connect, to formal and traceable downstream recovery routes. This study addresses the following research questions: (1) what pathways toward environmentally sound e-waste treatment are shared across the four countries, and (2) what critical factors enable the realization of these pathways. This study advances one core working hypothesis.

Hypothesis: *The environmentally sound e-waste management in the selected ASEAN member states is contingent upon the capacity to effectively recover e-waste, formalize the material flows and connect into traceable formal systems through domestic collection, institutional coordination, and, where appropriate, complementary transboundary recovery linkages.*

3. Data and analytical approach

This paper is based on the study results of ERIA research project² as following steps. First step is to review and summarize country chapters written by each country counterparts based on the literature survey by using publicly available information, including dataset provided from international organizations, enforced national laws and regulations, and official statistics and documents. Second is the field study to complement the result of the first step. Field surveys were conducted over several days in each country. The basic information of the field survey is summarized in Appendix 2.

Site visits were mainly carried out at e-waste recycling facilities, waste treatment companies, the related circular economy businesses and the relevant government agencies and other stakeholders. The authors conducted these field surveys with the same criteria for each member state, focusing on the following: (1) domestic collection and treatment practices, (2) the status quo of formal and informal sectors, (3) the structure of the domestic and international business relationships and customer networks, and (4) practical issues related to transboundary movements. Given the sensitivity of compliance and transboundary issues, identifying details of organizations and individuals were removed in the full report.

As a final step, stakeholder meetings were held in each country to validate the findings from the desk review and field visits. The meetings were organized by each local counterpart and our research group members, and invited the relevant stakeholders such as governmental officials, agencies and non-profit organizations. A brief overview of the stakeholder meeting is shown in Appendix 3.

This study adopts a comparative case study approach to conceptualize environmentally sound e-waste management as a supply chain consisting of (1) e-waste collection and capture from households and businesses, (2) pre-processing treatments such as

² An ERIA research project is “Research on Sound International Resource Circulation in ASEAN Region”. The results of the project are included in the research book, which consists of mainly four country reports: Malaysia, the Philippines, Thailand and Viet Nam.

dismantling, sorting, and concentration, and (3) downstream recovery such as high-value material recovery and refining. In addition, we consider how domestic pre-processing is connected to downstream recovery networks in overseas markets where relevant.

For each country, this study maps the key actors, material flows, and governance arrangements along these three stages. The cross-country comparison consists of four analytical dimensions: (1) legal and institutional frameworks including waste classification and EPR regulations, (2) e-waste collection systems and the role of informal sectors, (3) formal treatment capacity, and (4) traceability, enforcement, and transboundary downstream linkages. Because downstream recovery is often difficult to complete domestically, particular attention is paid to how domestic pre-processing is connected to overseas downstream recovery networks. Thereby, the structured comparisons among four ASEAN countries enable to identify the common patterns and challenges of e-waste management.

4. Results

4.1 Status quo and common pattern and challenges for e-waste treatment in the four selected ASEAN countries

A common pattern emerges across the four country cases. Environmentally sound e-waste management depends not merely on the existence of formal e-waste management facilities, but on whether escalating volumes of household e-waste are captured into traceable collection routes and linked to downstream recovery through the institutional system. Although the regulatory frameworks and treatment capacities differ across countries, all four cases reveal a similar bottleneck in the weak connection between actual household e-waste flows and formal treatment systems.

This section identifies the common patterns observed among four countries and shows the main differences in e-waste relevant policies and collection and treatment systems. Although the target countries in this paper have different regulatory frameworks and treatment capacities, they have mainly two common overarching challenges: rapidly increasing e-waste generation and only partially system development for environmentally sound collection and treatment.

As Section 2.2 summarised, although the scale and frequency of e-waste generation vary across the four countries, the general trend consistently increases in both volume and frequency. Despite this heterogeneity, the country studies reveal a common bottleneck in the weak linkage between household e-waste flows and formal treatment systems. Against this backdrop, the following analysis firstly synthesizes the country-specific results

related to their respective legislative instruments and policy frameworks.

Table 2 summarizes the e-waste relevant policies and legal framework among the four countries. In short, the implementation of EPR and related policy instruments remains uneven. According to Table 2, none of the four countries has a single comprehensive e-waste law. Instead, e-waste is mainly regulated through hazardous-waste, solid-waste, or import-control frameworks, depending on the country. The implementation of the EPR is diverse among the target countries. Viet Nam has already implemented the Decree No.08/2022/ND-CP to fulfil their responsibility to recycle products and packaging they manufacture and import. The Decree has covered the packaging and products from January 1, 2024, and manufacturers and importers of electrical and electronic products expect in some cases are subject to the regulation from January 1, 2025. Most recently, on April 1, 2026, Viet Nam issued Decree No. 110/2026/ND-CP on EPR regarding product and packaging recycling and waste treatment obligations of producers and importers. The Decree updates and supplements several provisions on EPR, including mechanisms for disbursing funds collected by the Vietnam Environmental Protection Fund, as well as clarifying the responsibilities of producers and importers in fulfilling EPR requirements.

Table 2: Summary of the e-waste relevant policies and legal framework among the selected countries

Country	E-waste classification and waste management framework	Extended Producer Responsibility (EPR) framework for EEE
Malaysia	Treated as scheduled hazardous waste and regulated mainly under Environmental Quality (Scheduled Wastes) Regulations 2005	Planned, but not yet in place
Philippines	Governed by Republic Act (RA) 6969 and Department of Environment and Natural Resources (DENR) Administrative Order (DAO) 2013-22. M506 mainly applies to Waste EEE (WEEE) and e-scrap managed through formal treatment storage and disposal (TSD) channels while M507 covers household and residential special wastes and may include household	Not yet in place (only for plastic packaging) EPR is mentioned in the draft DENR Department Administrative Order (DAO) on “Environmentally Sound Management of WEEE” being finalized

	WEEE.	
Thailand	Existing laws (e.g., Hazardous Substance Act (1992) and relevant announcements by Ministry of Commerce (MOC) and Department of Industrial Works (DIW)) provide partial control but lack comprehensive e-waste-specific regulation	In preparation
Viet Nam	Circular No. 02/2022/TT-BTNMT specifies types of EEE waste to be treated as hazardous. (Amended by Circular No. 07/2025/TT-BTNMT)	In force (Decree No. 08/2022/ND-CP, as amended by Decree No. 05/2025/ND-CP; Decree No.110/2026/ND-CP)

Source: Compiled by the authors based on relevant ministerial ordinances, regulations, and official legal materials published by the respective national authorities. Full details of the source materials are provided in the References

As summarized in Table 2, although the legal frameworks differ, they all face a similar practical problem. The issue is that household e-waste is not effectively captured into formal treatment channels.

Through this research, we found that the common bottleneck is not simply the absence of formal treatment facilities that the previous studies pointed out. Instead, the four countries suggest a persistent mismatch between the existence of licensed or formal treatment capacity and the actual material flows generated by households and small businesses. In all four countries, informal sectors continue to play a major role in collection, dismantling, and primary resource recovery because they are often more accessible, more flexible, and less costly than formal channels. As a result, a substantial share of e-waste does not enter traceable and environmentally sound treatment channels, even where licensed facilities are already in place.

However, as will be elaborated in the next section, there are important differences in the specific conditions across the countries. For instance, the informal collectors and illegal operators in Malaysia undermine the competitiveness and traceability of licensed recyclers. Although in the Philippines, the treatment storage and disposal (TSD) facilities for e-waste exist, most household e-waste still moves through informal channels. In

Thailand, formal collection remains weak because of the constraints of the budgetary, human-resource, and the relevant technologies even though 213 e-waste dismantling and recycling facilities are present, mainly central and eastern regions. Viet Nam also has licensed treatment facilities and advanced technologies, but their effectiveness is limited due to the unstable feedstock and competition with lower cost informal recyclers. Therefore, these findings illustrate that the main challenge is weak connectivity between household e-waste flows and formal treatment systems.

As mentioned above, there are differences in regulatory stringency, enforcement capacities, infrastructures for the treatment among ASEAN member states. Along with them, the second-hand markets and informal sectors are still expanding and dominant in this area. These country-specific contexts should be included and considered to achieve the proper e-waste treatment.

4.2 Country snapshots for e-waste management and frameworks

4.2.1 Malaysia

In Malaysia, the informal sector has played a major role in e-waste management, even though this country has established a formal regulatory framework. Informal sectors continue the practices such as open burning, acid baths, and rudimentary incineration, which generate the risk for the environment and occupational health, leading to weakened traceability and material quality. According to stakeholder information obtained during the field survey, we learned that approximately 1,000 informal collectors are active in Malaysia, compared with only about 200 formal recyclers.

As illustrated above, the formal treatment capacity is not necessarily absent in Malaysia. Through our survey, the country has a large number of licensed dismantlers and recyclers, and some operators have already employed advanced pre-processing and metallurgical routes to recover base and precious metals at high purities. A recycler we visited operates advanced metal refining and recovery processes, has obtained internationally recognized certifications such as ISO 14001, and targets multinational corporations as its primary customers. The company is connected to international supply chains and customer networks, while its activities are framed as being conducted in compliance with relevant laws and regulations. Furthermore, another company we visited engages in the refurbishment of electric appliances, indicating that formal business models in Malaysia have evolved beyond simply dismantling and recycling. However, there are some cases where many licensed factories operate below capacity because the e-waste collection system is immature and the volume of e-waste feedstock supply remains unstable. Moreover, the competitiveness of the formal sector weakens more because they must pay

higher compliance cost such as investment for environmental safeguards, worker safety, collection, transportation, and public-awareness effort.

In institutional term, the formal e-waste system in Malaysia is managed under the Environmental Quality (Scheduled Wastes) Regulations (2005) and the Prescribed Premises (Scheduled Wastes Treatment and Disposal Facilities) Regulations 1989 (Department of Environment Malaysia, 1989, 2005). While Malaysia does not yet have a law dedicated exclusively to household e-waste, e-waste is regulated as scheduled hazardous waste (SW) 110 with the Electronic Scheduled Waste Information System (eSWIS) already in operation for SW reporting and tracking, while Uniform Reporting System (URS) has been under development.

From the perspective of transboundary movements, e-waste importation is not allowed in principle, and DOE guidance permits only complete UEEE intended for direct reuse, repair, or refurbishment while imports for material recovery or disposal are prohibited (Department of Environment, 2021). Nevertheless, the law enforcement remains difficult in practice because misdeclaration, loopholes in trade classification and illicit inflows occur. Against the situation, Malaysian government has intensified enforcement through amendments to the Environmental Quality Act, joint operations with Customs and other agencies, and plans to strengthen EPR regulation, value-chain traceability, and green-technology partnerships (Ministry Natural Resources and Environmental Sustainability, 2025).

From the above, key challenges in Malaysia include the underutilization of licensed facilities, fragmented and inconsistent collection and dismantling systems, and the continued presence of unregistered operators. Moreover, some high-value e-waste fractions and partially recovered materials may still be sent overseas for further refining, reflecting continuing constraints in domestic recovery capacity and treatment technologies. Therefore, the underutilization of the formal sector and the weak connection between actual e-waste resources and formal facilities are more likely to be the main bottlenecks than the absence of formal treatment capacity in Malaysia. As a result, this country illustrates a form of systematic constraint in which comparatively advanced formal capacity exists, but actual e-waste flows are still only partially captured by traceable and formal channels.

4.2.2 Philippines

In the Philippines, the most e-waste from households still enters informal sectors rather than the licensed facilities despite the formal management framework for hazardous waste exists. A widespread informal network remains the dominant for household e-waste

disposal, so that environmentally unsound practices continue because many consumers may either store obsolete devices at home or dispose of them through informal collectors.

On the other hand, formal treatment capacity is not entirely absent in the Philippines. E-waste management in the Philippines is formally operated under the Republic Act (RA) 6969 and DAO 2013-22. According to the latter regulation, the industrial and business-origin E-scrap and WEEE handled by TSDs is covered by M506, while M507 refers more broadly to household and residential special wastes, which may include household WEEE but is not limited. Moreover, this country has 36 TSD facilities which are authorized to accept WEEE (M506) which have active one-year licenses from August 2025 until August 2026. However, most of them operate the manual dismantling and physical recovery while a small number of them provide the chemical or thermal processing, immobilization, or secure landfilling (Environmental Management Bureau (EMB), 2025, n.d.). In addition, the facilities are geographically unevenly distributed. More than 85 percent facilities locate in Luzon, and approximately 84 percent of them in Luzon are operated in Central Luzon and CALABARZON³ although only a few facilities serve the Visayas and Mindanao (Environmental Management Bureau (EMB), n.d.).

From the perspective of institutional framework, the Philippines is also embedded in Basel-related control procedures, and some TSD facilities are authorized to import electronic assemblies and scrap under regulated channels. At the same time, implementation remains complicated by issues such as the Prior Informed Consent (PIC) procedures, permit constraints, and legal ambiguities in special economic and freeport zones. In addition, field visits and stakeholder consultations further suggest that freeport zones such as Clark and Subic provide logistical and fiscal advantages that help explain why many licensed recyclers and TSD facilities are concentrated in Luzon.

Consequently, the Philippines case suggests that the central bottleneck lies not only in the total absence of formal facilities, but also in their limited territorial reach and weak institutional linkage with household e-waste flows. Hence, strengthening the formal system will require not only expanding licensed TSD capacity but also clarifying the legal framework more and extending compliant collection and pre-treatment beyond the main industrial corridors, including efforts to integrate informal collectors and to support community-based models such as upgraded barangay material recovery facilities.

4.2.3 Thailand

³ The region “CALABARZON” consists of five provinces on Luzon Island, and its name is derived from the first syllables of Cavite (CA), Laguna (LA), and Batangas (BA), the first letter of Rizal (R), and the last syllable of Quezon (ZON).

In Thailand, the proportion of e-waste collected and recycled through the formal system remains low compared to the total volume of waste (ASIA GREEN RESCRAP COMPANY LIMITED, 2025), and particularly, the informal collection and dismantling remain predominant in the circulation of household e-waste. The informal sectors are often the most immediate and practical interface for households disposing of obsolete devices. While these informal activities can recover valuable materials, they also cause environmental risks by the inadequate management of hazardous waste and materials.

Meanwhile, the formal sorting and recycling facilities are not entirely absent from Thailand. A sorting and recycling company visited served mainly foreign-invested enterprises and major domestic manufactures, suggesting that transaction requirements and quality standards may be linked to international business practices. Moreover, there are 213 dismantling and recycling factories of e-waste, mainly located in the central and eastern regions (Senate Commission on Commerce and Industry, 2022).

In terms of regulation, the Thai government has enforced the environmental regulation such as the Hazardous Substances Act (1992) and is preparing an EPR scheme for e-waste. Thailand has adopted a strict approach to transboundary e-waste movement by banning e-waste imports under a notification from the Ministry of Commerce (2020), while exports remain subject to the Basel Convention and the domestic laws of destination countries. However, some domestically generated e-waste still has to be exported for further processing because advanced recycling and high-tech metal recovery facilities remain limited in Thailand. In addition, local governments are primarily responsible for collecting household e-waste from communities, and transportation and disposal fees are set according to relevant regulations. However, implementation of these regulations remains limited in practice. According to our survey, many local governments face constraints in budget, human resources, and technological capacity.

In this sense, the persistence of informal sectors is associated with the absence of sufficiently accessible and effective formal collection channels, the insufficient legislative framework and weak enforcement. In other words, upstream collection remains weak and fragmented, preventing sufficient material from entering formal channels although formal facilities exist downstream. This problem is further compounded by the absence of integrated legal framework covering the entire e-waste management chain.

4.2.4 Viet Nam

The volume of e-waste generation in Viet Nam has grown with rapid urbanization, rising incomes and expanding the consumption of the electrical equipment. Consistent with the situation on other country cases, the informal sectors, including scrap dealers, waste

collectors, service shops, and craft villages, still handle the e-waste management in Viet Nam. E-waste management in the informal sector rely heavily on manual dismantling, open burning, and acid leaching of PCBAs, which generate serious environmental and occupational-health risks while eroding traceability. In many regions, households still sell obsolete devices to informal collectors because formal collection system remains underdeveloped in Viet Nam.

Institutionally, Viet Nam does not yet have a single comprehensive definition of e-waste, but hazardous EEE waste is specified in Circular No. 02/2022/TT-BTNMT⁴. Furthermore, Decree No. 08/2022/ND-CP has established an EPR framework for producers and importers⁵, although the implementation remains at an early stage. As a post-fieldwork legal update, Viet Nam issued Decree No. 110/2026/ND-CP⁶, providing detailed provisions on EPR, including responsibilities, requirements, implementation roadmaps, applicable entities, recycling rates, and related mechanisms. From the perspective of transboundary movements, Viet Nam also prohibits the import of e-waste in principle, while allowing certain scrap imports under pre-permitted arrangements. However, monitoring remains difficult because customs and waste-control classifications remain only partially harmonized. Although Viet Nam prohibits the import of e-waste in principle, trade data indicate continuing e-waste related material flows. These flows may reflect legally permitted scrap imports for production inputs, classification discrepancies, or enforcement gaps. Moreover, illegal imports and misdeclaration also remain a concern, with authorities addressing numerous cases between 2020 and 2023.

At the same time, formal treatment capacity is not entirely absent in Viet Nam. A waste management company which we visited during the field survey undertakes some household e-waste collection and treatment, although its core business remains the collection, transportation, and treatment of industrial hazardous waste, as well as the trading of scrap and recycled products. As of 2020, Viet Nam had 117 licensed hazardous-waste treatment facilities, with 75 companies authorized to handle major e-waste-related categories (Ministry of Natural Resources and Environment, 2021). In the formal e-waste sector, technologies range from pre-processing methods such as dismantling, shredding, and mechanical sorting to end-processing methods such as pyrometallurgy, hydrometallurgy, bioleaching, and PCBA-targeted recovery lines.

⁴ Amended by Ministry of Natural Resources and Environment Circular No. 07/2025/TT-BTNMT dated 28 February 2025 on Detailing a Number of Articles of Law on Environmental Protection.

⁵ Amended by Decree No. 05/2025/ND-CP dated 6 January 2025 Detailing a Number of Articles of the Law on Environmental Protection.

⁶ Decree No. 110/2026/ND-CP dated 1 April 2026 Detailing a Number of Articles of the Law on Environmental Protection.

However, the effectiveness of formal treatment remains constrained by small plant scale, unstable feedstock, competition from low-cost informal recyclers, and limited investment. In addition, domestic recycling technologies for precious-metal recovery remain incomplete and selected high-value fractions continue to be exported to countries with more advanced refining capacity.

In this sense, the Viet Nam case suggests that the central bottleneck lies not in the complete absence of formal technological capacity, but in the weakness and insufficiency of a comprehensive and effective e-waste management system capable of handling increasing waste volumes in an environmentally sound manner.

5. Discussion

Overall, our findings support the main arguments of previous studies on e-waste management in developing economies, while also extending them in three important respects that address the gaps identified in the literature review. First, with regard to institutional and regulatory weaknesses, our findings confirm the existence of formal legal frameworks in all four countries; however, they reveal a more specific problem: system misalignment, in which formal capacity is poorly integrated into actual material flows rather than simply absent. Second, with regard to the informal sector, the cross-country comparison reinforces the importance of the informal sector (Ezeah et al., 2013), and suggests that several institutional prerequisites for their effective integration remain underdeveloped. Third, regarding transboundary e-waste flows, our findings demonstrate that the more binding constraint lies in the weakness of domestic collection systems rather than in cross-border movements per se; and that regulated transboundary linkages, connecting domestic pre-processing to downstream international recovery networks, may serve a complementary rather than a competing function. This finding directly addresses the gap identified in the literature review, particularly the limited attention paid to how regulated transboundary linkages might complement domestic e-waste management systems (Awasthi & Li, 2017; Shinkuma & Huong, 2009).

Consistent with this previous literature, our case studies exhibit a consistent pattern: although legal frameworks for hazardous and solid waste management are in place, however significant limitations on environmentally sound management still exist. These limitations include low formal collection rates, uneven geographical distribution of treatment facilities, insufficient data systems, and weak implementation capacity. This implies that e-waste management in developing economies entails not merely the legislative and institutional establishment, but also the strengthening of administrative, financial, and logistical capacities to make such arrangements function effectively in

practice.

Across the four country cases, government awareness of informal sectors and isolated public private cooperation exist. However formal legal protection for informal and unregistered operators, organised cooperative structures and systematic partnership mechanisms remain largely absent. This implies that calls for formalisation are still limited to the required institutional prerequisites. In this respect, the issues identified by Akenji et al. (2011) more than ten years ago persisted. A combined approach is needed that acknowledges the operational role of the informal sector while progressively building the legal and organizational conditions for their integration. Even in member states with formal recycling capacity, such as Malaysia and Viet Nam, informal practices continue to divert materials away from licensed operators, undermine recovery efficiency, and increase environmental and occupational health risks.

Beyond confirming existing findings, this study contributes two specific extensions to the literature on transboundary e-waste flows, an area in which the gaps identified in the literature review are particularly pronounced. The first extension concerns the relative weight of domestic versus transboundary constraints. The most immediate bottleneck on environmentally sound e-waste management lies not in transboundary movement, but rather the weakness of domestic collection systems, legislative enforcement, implementation capacities, traceability, and feedstock instability (Awasthi & Li, 2017; Shinkuma & Huong, 2009). Import controls, misdeclaration, and downstream export linkages remain policy concerns in several country cases, but they do not alter the finding that weak domestic collection is the more binding constraint. This challenges the framing of prior literature which placed primary emphasis on restricting cross-border movements, and redirects attention toward building effective domestic collection channels as the foundational precondition for environmentally sound e-waste management.

The second extension focuses on the role of transboundary linkages in complementing domestic systems. Previous literature has framed transboundary e-waste primarily as a problem of illegal flows to be controlled. This study proposes a different approach: where domestic collection systems are strengthened and traceability is secured, regulated connections between domestic pre-processing and international downstream recovery networks can stabilize the situation for formal recyclers, rather than simply diverting materials from domestic processing. This is especially relevant in contexts such as the Philippines and Thailand, where advanced downstream recovery capacity remains limited domestically. In such settings, regulated export linkages, subject to monitoring and border controls, may help secure reliable downstream outlets for pre-processed materials and improve the economic viability of formal e-waste management.

A further contribution of this study is to provide a critical corrective to the view that frames developing contexts solely through the lens of infrastructural deficiency. We consider the concept of system misalignment which offers a corrective to the deficiency framing that has dominated the foundational literature (Osibanjo & Nnorom, 2007; Widmer et al., 2005). All four countries possess some form of legal or regulatory framework, some degree of licenced treatment capacity, but advanced downstream recovery is much more uneven, being more developed in Malaysia and parts of Viet Nam than in the Philippines and Thailand. Moreover, some formal facilities also possess internationally recognized certifications such as ISO 14001, and advanced processing capabilities, indicating that formal technical capacity is not entirely absent. These indicate that the fundamental problem is not the absolute absence of formal institutions or technical capacities, but misalignment, uneven distribution, and weak integration of those formal systems within e-waste material flows. In other words, formal treatment facilities are underutilised because feedstock supply is unstable and insufficient, which is a consequence of informal sectors dominating collection and weak linkages between household e-waste generation and formal collection channels. Under the situation, e-waste management business becomes unviable because of unprofitability and uncertainty.

These findings provide two policy implications. First, effective proper e-waste management in developing countries requires more than legislation: EPR regulations and formal classification (registration) systems should be accompanied by investment for e-waste collection infrastructure, standardized classification and reporting systems, enforcement mechanisms, and downstream treatment capacity. Second, policy design for environmentally sound e-waste management should move beyond a binary formal-informal distinction. Given that informal sectors are deeply embedded in the collection and dismantling process across all four cases, involuntary transition into the formal sector is exceedingly unlikely to be effective. Therefore, a more effective and pragmatic approach would entail the integration of incentive-based mechanisms, encompassing registration assistance, training, monitoring, and collaboration with accredited facilities, with measures aimed at stabilizing feedstock supply for formal recyclers. Therefore, it is proposed that the enhancement of domestic collection channels, in conjunction with the judicious management of transboundary linkages under strict regulation, could function as a complementary mechanism for the stabilization of formal resource flows through licensed facilities.

A key operational implication of these findings concerns the sequencing of policy interventions. The fundamental precondition for enhancing domestic collection systems is the implementation of strategies that promote infrastructural development, ensure the

enforcement of classification and reporting standards, and facilitate the integration of informal sectors into formal channels. Without a functioning domestic collection system, regulated transboundary linkages cannot serve their intended purpose: feedstock that is not captured into formal channels domestically cannot be channelled into traceable international downstream recovery either.

Once domestic collection is sufficiently developed, connections between domestic pre-processing and export-linked downstream recovery can serve as a complement, particularly in country contexts such as the Philippines and Thailand where advanced domestic processing capacity remains limited. Such transboundary linkages should not be treated as a substitute for domestic capacity-building, but as one mechanism for stabilizing formal resource flows through licensed facilities, improving economic viability, and making formal e-waste management systems self-sustaining over time. For this complementary function to be realized, transboundary linkages must be supported by robust monitoring, traceability systems, and effective border controls, the institutional infrastructure that prior literature on illegal cross-border movements has called for, repurposed here in service of regulated and beneficial flows.

In summary, these findings broadly support the working hypothesis by showing that environmentally sound e-waste management depends not only on the existence of formal treatment capacity, but also on the capacity to capture household e-waste, formalize material flows, strengthen traceability, and connect domestic pre-processing to appropriate downstream recovery routes.

6. Conclusions

This paper examines the conditions under which more environmentally sound e-waste treatment may emerge in four ASEAN member states, namely Malaysia, the Philippines, Thailand, and Viet Nam, through comparative country case studies based on documentation reviews, available statistics, field visits, and stakeholder meetings. In particular, this study addressed two research questions: first, what pathways toward environmentally sound e-waste treatment are shared across the selected countries, and second, what factors enable the realization of such pathways.

The analysis suggests that the four selected countries encounter a single shared, broad and common bottleneck. Household e-waste is still not sufficiently connected to formal collection and treatment systems. In this regard, the primary challenge lies not simply the absence of legal frameworks or treatment facilities. Rather, the findings suggest that a persistent mismatch remains between the existence of licensed or formal treatment

capacity and the actual material flows generated by households and small businesses. In all four cases, informal sectors continue to play an important role in collection, dismantling, and primary resource recovery. In contrast formal facilities often remain limited in scale, uneven in territorial reach, or unstable in feedstock supply.

These findings suggest that environmentally sound e-waste management in the selected ASEAN countries is contingent not on legal classification or the mere existence of treatment facilities, but rather on the ability to capture and channel household-generated e-waste into traceable formal routes. At the same time, the findings also imply that the issue should not be understood only as one of infrastructural absence. In all four countries, some degree of formal treatment capacity, regulatory structure, and technological capability already exists. However, these formal systems remain only partially connected to the actual circulation of e-waste. Therefore, the more fundamental problem is the weak alignment between formal systems and actual material flows.

From a policy perspective, the results indicate that improving e-waste management in the ASEAN region requires more than introducing formal regulations such as EPR mandates alone. Greater attention needs to be directed towards domestic collection systems, traceability and reporting, enforcement capacity, and institutional coordination among relevant actors. At the same time, the findings also suggest that policy design should move beyond a simple dichotomy between formal and informal sectors. In practice, more pragmatic approaches may involve stricter environmental control in conjunction with incentives for registration, monitoring, training, and cooperation between informal sectors and licensed facilities.

This study also suggests that securing more stable supply for formal e-waste management systems is a key component to improve the viability and effectiveness of licensed facilities. In this regard, the higher priority is to strengthen the domestic collection system. Besides, transboundary downstream linkages may still play a complementary role, help stabilize resource flows and improve the utilization of formal recycling capacity, especially where recycling capacities and advanced technologies remain limited in domestic settings. Hence, cross-border supply chain should be regarded as one potential solution that depends mainly on domestic governance capacity, traceability, and effective monitoring.

Finally, this study has several limitations. It covers only four country cases and relies on a combination of desk review, available public information, field visits, and stakeholder meetings conducted within a limited time and regional framework. In addition, cross-country comparison is still subject to some limitations because data on formally collected

and recycled e-waste are still incomplete or uneven across the selected countries. Hence, future research should expand the target countries within ASEAN, strengthen the empirical tracing of actual material flows, and examine more closely how domestic collection, informal-sector dynamics, and downstream recovery linkages can be aligned over time.

Acknowledgement

This study is based on a part of the findings from the research project of the Economic Research Institute for ASEAN and East Asia (ERIA) bearing the titled “Research on Sound International Resource Circulation in ASEAN Region”, financially supported by the Ministry of the Environment, Japan (MOEJ). The authors would like to express their appreciation to ERIA and MOEJ, as well as to the country study counterparts including, Sunway University (Malaysia), Environweave Integrative Environmental Research (the Philippines), Thailand Environmental Institute (Thailand) and Natural Resources and Environmental Economics, Institute of Strategy and Policy on Agriculture and Environment (Viet Nam). They prepared the respective country reports, engaged in constructive discussions with us, providing invaluable insights and generous cooperation, and arranging interviews, field visits, and stakeholder meetings. The authors extend their gratitude the interviewees and participants in the stakeholder meetings in four countries for their valuable cooperation and insights. An earlier version of this paper was presented at “The 3R International Scientific Conference on Material Cycles and Waste Management” held in March 2026, and the authors are grateful to the participants for their constructive comments and suggestions.

References

- Akenji, L., Hotta, Y., Bengtsson, M., & Hayashi, S. (2011). EPR policies for electronics in developing Asia: an adapted phase-in approach. *Waste Management & Research*, 29(9), 919-930. <https://doi.org/10.1177/0734242X11414458>
- Andeobu, L., Wibowo, S., & Grandhi, S. (2021). A Systematic Review of E-Waste Generation and Environmental Management of Asia Pacific Countries. *International Journal of Environmental Research and Public Health*, 18(17), 9051. <https://doi.org/10.3390/ijerph18179051>
- ASIA GREEN RESCRAP COMPANY LIMITED. (2025). Management of E-waste in Thailand [Conference presentation]. *Management of E-waste in Thailand [Conference presentation]. The Stakeholder Meeting on Resource Circulation from EEE in ASEAN – Thailand Case, Bangkok, Thailand.*, (16 July, 2025).
- Awasthi, A. K., & Li, J. (2017). Management of electrical and electronic waste: A comparative evaluation of China and India. *Renewable and Sustainable Energy Reviews*, 76, 434-447. <https://doi.org/10.1016/j.rser.2017.02.067>
- Baldé, C. P., Kuehr, R., Yamamoto, T., McDonald, R., D'Angelo, E., Althaf, S., Bel, G., Deubzer, O., Fernandez-Cubillo, E., Forti, V., Gray, V., Herat, S., Honda, S., Iattoni, G., Khatriwal, D. S., Cortemiglia, V. L. d., Lobuntsova, Y., Nnorom, I., Pralat, N., & Wagner, M. (2024). *Global E-waste Monitor 2024*. International Telecommunication Union (ITU) and United Nations Institute for Training and Research (UNITAR), Geneva/Bonn. https://ewastemonitor.info/wp-content/uploads/2024/12/GEM_2024_EN_11_NOV-web.pdf
- Department of Environment. (2021). Guidelines for the Transboundary Movement of Used Electrical and Electronic Equipment (UEEE) in Malaysia. <https://www.doe.gov.my/wp-content/uploads/2021/07/Guidelines-for-the-Transboundary-Movement-of-Used-Electrical-and-Electronic-in-Malaysia.pdf>
- Department of Environment and Natural Resources (DENR). (2013). *Revised Procedures and Standards for the Management of Hazardous Wastes (Revising DAO 2004-36)*. Retrieved from <https://emb.gov.ph/wp-content/uploads/2025/02/DAO-2013-22-Procedures-and-Standards-for-Hazwaste-1.pdf>
- Department of Environment Malaysia. (1989). *Environmental Quality (Prescribed Premises) (Treatment and Disposal Facilities for Scheduled Waste) Regulations 1989 [P.U. (A) 253/2006]*. Retrieved from https://gunungganang.com.my/pdf/Malaysian-Legislation/National/Environmental%20Quality%20_Prescribed%20Premises_Scheduled%20Wastes%20Treatment%20And%20Disposal%20Facilities_%20Regulations%201989.pdf
- Department of Environment Malaysia. (2005). *Environmental Quality (Scheduled Wastes) Regulations 2005 [P.U. (A) 294/2005]*. Retrieved from https://www.doe.gov.my/wp-content/uploads/2021/08/Environmental_Quality_Scheduled_Wastes_Regulations_2005_-_P.U.A_294-2005.pdf
- Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical

- and electronic equipment (WEEE), Annex IV, L 197 38-71 (2012).
<http://data.europa.eu/eli/dir/2012/19/oj>
- Environmental Management Bureau (EMB). (2025). Hazardous Waste Management Section presentation. *Basel Ban Impact Assessment Workshop. August 8, 2025.*
- Environmental Management Bureau (EMB). (n.d.). *Hazardous waste management data* (<https://emb.gov.ph/hazardous-waste-management-data/>)
- Ezeah, C., Fazakerley, J. A., & Roberts, C. L. (2013). Emerging trends in informal sector recycling in developing and transition countries. *Waste Management*, 33(11), 2509-2519. <https://doi.org/10.1016/j.wasman.2013.06.020>
- Liu, K., Tan, Q., Yu, J., & Wang, M. (2023). A global perspective on e-waste recycling. *Circular Economy*, 2(1), 100028. <https://doi.org/10.1016/j.ccc.2023.100028>
- Ministry Natural Resources and Environmental Sustainability. (2025, 8 May, 2025). *Keynote Address YB Nik Nazmi Nik Ahmad Minister of Natural Resources and Environmental Sustainability for Nordic Day Panel Seminar "Partnering for a Greener Future" [Speech]*. Retrieved 29 October, 2025 from <http://myagric.upm.edu.my/id/eprint/23878>
- Ministry of Natural Resources and Environment. (2021). National Environmental Status Report 2016-2020. *Hanoi, Vietnam.*
- Ministry of Natural Resources and Environment (MONRE). (2022). Circular No. 02/2022/TT-BTNMT - Detailing a number of articles of law on environmental protection.
- Ministry of Natural Resources and Environment (MONRE). (2025). Circular No. 07/2025/TT-BTNMT dated 28 February 2025 on Detailing a Number of Articles of Law on Environmental Protection.
- Neves, S. A., Marques, A. C., & de Sá Lopes, L. B. (2024). Is environmental regulation keeping e-waste under control? Evidence from e-waste exports in the European Union. *Ecological Economics*, 216, 108031. <https://doi.org/10.1016/j.ecolecon.2023.108031>
- Notification of the MOC on Prohibiting the Import of Electronic Waste B.E. 2563. (2020). Royal Gazette, 137(special 209d), p.12. (14 September 2020). <https://www.dft.go.th/th-th/Detail-Law/ArticleId/16129/16129>
- Notification of the MOC on Prohibiting the Import of Plastic Scrap B.E.2567. (2024). *Royal Gazette*, 141(special 345d). Retrieved 28 November, 2025 from <https://www.dft.go.th/th-th/Detail-Law/ArticleId/28726/-1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18-19-20-21-22-23-24-25-26-27-28-29-30-31-32-33-34-35-36-37-38-39-40-1>
- Osibanjo, O., & Nnorom, I. C. (2007). The challenge of electronic waste (e-waste) management in developing countries. *Waste Manag Res*, 25(6), 489-501. <https://doi.org/10.1177/0734242X07082028>
- Republic of the Philippines. (1990). Toxic Substances and Hazardous and Nuclear Wastes Control Act of 1990, Republic Act No. 6969. <https://emb.gov.ph/wp-content/uploads/2015/12/RA-6969.pdf>
- Senate Commission on Commerce and Industry. (2022). *Report on industrial policies and urban mining initiatives in Thailand*. Retrieved 4 November, 2025 from <https://www.senate.go.th>
- Shahabuddin, M., Uddin, M. N., Chowdhury, J. I., Ahmed, S. F., Uddin, M. N., Mofijur, M., & Uddin, M.

- A. (2023). A review of the recent development, challenges, and opportunities of electronic waste (e-waste). *International Journal of Environmental Science and Technology*, 20(4), 4513-4520. <https://doi.org/10.1007/s13762-022-04274-w>
- Shinkuma, T., & Huong, N. T. M. (2009). The flow of E-waste material in the Asian region and a reconsideration of international trade policies on E-waste. *Environmental Impact Assessment Review*, 29(1), 25-31. <https://doi.org/10.1016/j.eiar.2008.04.004>
- Shinkuma, T., & Nguyen Thi Minh, H. (2009). The flow of E-waste material in the Asian region and a reconsideration of international trade policies on E-waste. *Environmental Impact Assessment Review*, 29(1), 25-31. <https://doi.org/10.1016/j.eiar.2008.04.004>
- Thailand. (1992). Hazardous Substances Act, B.E. 2535, Royal Gazette. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/<http://law.industry.go.th/laws/file/61391>
- The Socialist Republic of Viet Nam. (2022). Decree No. 08/2022/ND-CP dated 10 January 2022 Detailing a number of articles of the Law on Environmental Protection.
- The Socialist Republic of Viet Nam. (2025). Decree No. 05/2025/ND-CP dated 6 January 2025 Detailing a Number of Articles of the Law on Environmental Protection.
- The Socialist Republic of Viet Nam. (2026). Decree No. 110/2026/ND-CP dated 1 April 2026 Detailing a Number of Articles of the Law on Environmental Protection.
- Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., & Böni, H. (2005). Global perspectives on e-waste. *Environmental Impact Assessment Review*, 25(5), 436-458. <https://doi.org/10.1016/j.eiar.2005.04.001>

Appendix 1: Non-exhaustive list of e-waste under the six categories

Category	Non-exhaustive e-waste
Temperature exchange equipment	Refrigerators, Freezers, Equipment which automatically delivers cold products, Air conditioning equipment, Dehumidifying equipment, Heat pumps, Radiators containing oil and other temperature exchange equipment using fluids other than water for the temperature exchange.
Screens, monitors, and equipment containing screens having a surface greater than 100 cm ²	Screens, Televisions, LCD photo frames, Monitors, Laptops, Notebooks.
Lamps	Straight fluorescent lamps, Compact fluorescent lamps, Fluorescent lamps, High intensity discharge lamps - including pressure sodium lamps and metal halide lamps, Low pressure sodium lamps, LED.
Large equipment	Washing machines, Clothes dryers, Dish washing machines, Cookers, Electric stoves, Electric hot plates, Luminaires, Equipment reproducing sound or images, Musical equipment (excluding pipe organs installed in churches), Appliances for knitting and weaving, Large computer-mainframes, Large printing machines, Copying equipment, Large coin slot machines, Large medical devices, Large monitoring and control instruments, Large appliances which automatically deliver products and money, Photovoltaic panels.
Small equipment	Vacuum cleaners, Carpet sweepers, Appliances for sewing, Luminaires, Microwaves, Ventilation equipment, Irons, Toasters, Electric knives, Electric kettles, Clocks and Watches, Electric shavers, Scales, Appliances for hair and body care, Calculators, Radio sets, Video cameras, Video recorders, Hi-fi equipment, Musical instruments, Equipment reproducing sound or images, Electrical and electronic toys, Sports equipment, Computers for biking, diving, running, rowing, etc., Smoke detectors, Heating regulators, Thermostats, Small Electrical and electronic tools, Small medical devices, Small Monitoring and control

	instruments, Small Appliances which automatically deliver products, Small equipment with integrated photovoltaic panels.
Small IT and telecommunication equipment (no external dimension more than 50 cm)	Mobile phones, GPS, Pocket calculators, Routers, Personal computers, Printers, Telephones.

Source: "Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE), Annex IV" (2012)

Appendix 2: A Summary of Field Survey Schedule

Country	Date	Local Counterpart	Main Destinations
Malaysia	August 2025	Sunway University	● E-waste Recyclers ● Refurbishing and Remanufacturing Companies ● Government Agencies
Philippines	September 2025	Environweave Integrative Environmental Research	● E-waste Recyclers ● Business Associations ● Government Agencies
Thailand	July 2025	Thailand Environmental Institute (TEI)	● E-waste Recyclers ● E-waste Treatment Technology Center
Viet Nam	August 2025	Natural Resources and Environmental Economics, Institute of Strategy and Policy on Agriculture and Environment (ISPAE)	● E-waste Recyclers ● Formal Collection Point ● Second-hand EEE Shop

Notes: Beyond the elements in the table above, the local counterparts themselves conducted field research and interviews when the full project report is prepared. The information provided in the table is limited to the field visits where the authors participated.

Source: Compiled by the authors

Appendix 3: A Brief Overview of the Stakeholder Meeting

Country	Date	Main Participating Stakeholders
Malaysia	August 27, 2025	● Government Agencies and Authorities ● E-waste Recyclers ● Recycling Platform Tech Providers ● E-waste Collectors ● Remanufacturing Companies ● Researchers
Philippines	September 11, 2025	● Government Agencies and Authorities ● E-waste Recyclers ● International Organizations ● Non-Governmental Organizations ● Academic Institutions ● Consultants
Thailand	July 16, 2025	● Government Agencies and Authorities ● E-waste Recyclers
Viet Nam	August 21, 2025	● E-waste Recyclers ● Private Consultants ● Academic Institutions

Source: Compiled by the authors

