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ANALYZING REGULATIONS ON ELECTRONIC WASTE MANAGEMENT: A COMPARATIVE STUDY OF INDONESIA AND THE UNITED STATES

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Abstract: *Indonesia generated an estimated 1.6 million tons of electronic waste in 2019, yet no Indonesian statute or regulation addresses e-waste as a distinct legal category, and most of it is handled by an informal sector that burns, dumps, or acid-leaches discarded devices. This article compares the legal frameworks and institutional structures through which Indonesia and the United States regulate e-waste, and it asks which elements of the American approach can be adapted to Indonesian conditions. Using normative juridical research with statutory, comparative, and conceptual approaches, it examines the Waste Management Law, the hazardous waste regulations and their implementing ministerial rules, the EPA's rule on cathode ray tubes (EPA-HQ-RCRA-2004-0012), and state-level extended producer responsibility (EPR). It finds that Indonesian provisions on e-waste are implicit and scattered across general waste and hazardous waste instruments, whereas the United States combines a federal hazardous waste rule with state EPR systems and EPA planning tools, albeit without full national uniformity. Drawing on EPR theory and on the comparative-law literature on legal transplants, the article proposes a dedicated e-waste regime built on a binding classification, producer take-back obligations, technical processing standards, and the legal recognition of informal collectors.*

Keywords: Comparative Law; E-Waste; Extended Producer Responsibility; Hazardous Waste; Indonesia

1. Introduction

Advances in information technology and electronic devices have made many aspects of human life easier. Alongside these benefits, however, a major problem has emerged in the form of rising electronic waste. The resulting debris, officially termed waste electrical and electronic equipment (WEEE), is commonly referred to as "e-waste" (Ramírez Restrepo & Baars, 2025). It comprises a range of devices, including mobile phones, computers, televisions, refrigerators, and other electronic goods that no longer function or are no longer used. According to the Global E-Waste Monitor 2020 published by the United Nations (UN), the global volume of e-waste reached approximately 53 million tons in 2019 (Rahman, 2022). This figure is projected to rise sharply to 74 million tons by 2030 and to as much as 120 million tons by 2050 (Rahman, 2022). Yet only about 17.4% of all e-waste, which contains both hazardous substances and valuable metals, is collected, managed, and recycled through environmentally sound methods that meet established standards (Rahman, 2022).

For Indonesia, the UN estimated e-waste generation at approximately 1.6 million tons in 2019 (Rahman, 2022). Data from the Directorate General of Waste, Hazardous and Toxic Waste Management (PSLB3) of the Ministry of Environment and Forestry (KLHK)

indicate that the figure has continued to rise and was projected to exceed 2 million tons in 2021 (Rahman, 2022). Illegal exports and the donation of electronic equipment, particularly obsolete computers, from developed to developing countries aggravate the growth in global e-waste volumes (Rahman, 2022). Only about a quarter of all e-waste currently passes through formal recycling facilities that observe worker protection standards (Rahman, 2022). The health effects of direct exposure during recycling and of the environmental contamination caused by e-waste have not been thoroughly studied (Rahman, 2022). Inconsistent findings, unclear correlations, and weak study designs have meant that researchers rarely establish a causal link between informal employment in e-waste recycling and health outcomes; only musculoskeletal disorders and work-related injuries can be attributed directly to such employment, as Issah et al. have also described for the African continent (Eckhardt & Kaifie, 2024).

In Indonesia, e-waste management grows more complex as the use of electronic devices increases, while the management system itself still functions poorly. A major obstacle is the absence of a clear and comprehensive policy on e-waste. A policy framework does exist to protect vulnerable groups from the dangers of e-waste, but its implementation in the field is often ineffective (Rahman, 2022). The relevant rules still refer to Law Number 18 of 2008 on Waste Management and Government Regulation Number 101 of 2014 on the Management of Hazardous and Toxic Waste, both of which are general in scope and do not address e-waste specifically. In practice, e-waste management in Indonesia remains limited, and the informal sector is responsible for the open dumping of e-waste that causes considerable environmental degradation (Kabul, Lisa M. Lautetu, M. Bayu Rizky Prayoga, Caecilia Meyta R, & Defi Darylianty Debora, 2024). Informal practices such as open burning or soaking components in acid to extract metals pose high risks to health and the environment (Kabul et al., 2024).

Unregulated recycling of e-waste produces several significant environmental impacts (Kabul et al., 2024). Dismantling and processing used devices can contaminate soil, air, and water through the release of hazardous substances, including mercury, lead, cadmium, nickel, and various toxic organic compounds (Kabul et al., 2024). E-waste containing toxic materials is also frequently discarded together with ordinary household waste in landfills, where leachate can carry hazardous chemicals into soil and surface water (Kabul et al., 2024). Air pollution adds a further problem: open burning and soldering for metal extraction release toxic emissions such as dioxins and elevated concentrations of heavy metals, which endanger both the environment and human health (Kabul et al., 2024).

The spread of artificial intelligence (AI) raises the prospect of a further surge in e-waste, particularly from AI data centres and from increasingly sophisticated systems such as generative AI. Generative AI demands substantial computing resources for model training and inference, yet the e-waste it generates and the strategies for managing that waste remain underexplored (Wang, Zhang, Tzachor, & Chen, 2024). Its cumulative e-waste is projected to reach between 1.2 and 5.0 million tons over the 2020–2030 period, depending on the scenario of future AI development (Wang et al., 2024).

These figures expose a conceptual difficulty that shapes the legal analysis that follows. E-waste is at once a hazard and a resource. It contains toxic substances that justify its

treatment as hazardous waste, and it contains copper, precious metals, and high-grade plastics whose recovery has real economic value (Shahabuddin et al., 2023). Recent work on the reuse of e-waste in functional materials shows how much of this value depends on careful sorting and contaminant management at the earliest stages of handling (Niu et al., 2025). A legal regime that sees only the hazard will push e-waste toward containment and disposal, while a regime that sees only the resource will tolerate the unsafe extraction practices of the informal sector. The task of regulation is to hold both dimensions together: to channel e-waste toward recovery while confining its hazardous fractions to facilities able to treat them safely. Whether Indonesian and American law succeed in this task is the underlying question of the comparison.

The United States, unlike Indonesia, has established e-waste management rules through the Environmental Protection Agency (EPA) rule docketed as EPA-HQ-RCRA-2004-0012, supported by state-level regulation (Universal Eco, n.d.). A comparison between the two countries makes it possible to identify policy strategies that each has applied within its own social and institutional context, to locate the regulatory gaps in Indonesia, and to formulate solutions grounded in relevant practice. The inquiry also bears on the Sustainable Development Goals (SDGs), particularly Goal 12 on responsible consumption and production and Goal 3 on health and well-being (United Nations, n.d.). A more comprehensive e-waste policy would allow Indonesia to reduce the burden on the environment and public health while opening economic opportunities through a circular economy, and the American experience offers material for building a more transparent and sustainable system of e-waste governance.

Comparison, however, carries its own risk. Kahn-Freund (1974) warned that legal rules do not travel equally well between systems: rules closely bound to a particular distribution of political power and institutional capacity resist transplantation, and the comparatist who ignores this misuses comparative law. Extended producer responsibility (EPR), the centrepiece of most e-waste regimes, illustrates the point. The OECD (2016) defines EPR as an environmental policy approach that extends the producer's responsibility for a product to the post-consumer stage of its life cycle, shifting the financial and organizational burden of waste management from municipalities to producers in keeping with the polluter-pays principle. Kojima et al. (2009), studying China and Thailand, show that this approach meets particular difficulties in developing countries, where informal collectors who pay consumers for discarded devices outcompete formal take-back systems and where weak monitoring allows free-riding by producers and importers. Any lesson that Indonesia draws from the United States must therefore pass through the filter of these conditions.

Several earlier studies have examined the challenges of e-waste management in Indonesia by comparison with developed countries such as the United States. Raharjo and Utomo (2022) used a SWOT analysis to evaluate the strengths and weaknesses of Indonesia's e-waste system relative to developed states and recommended an EPR model comparable to that applied in the United States. Maheswari, Yudoko, and Adhiutama (2019) highlighted the crucial role of regulatory support and private-sector incentives in implementing reverse logistics, which in Indonesia still operates informally. Rahmanda, Njatrijani, and Fadillah (2023) pointed out that Indonesian regulations

remain general and do not yet address the technical aspects of e-waste collection and recycling, in contrast to the developed legal frameworks and environmental certification standards of the United States, such as R2 and e-Stewards.

This study asks how the regulation of e-waste management compares between Indonesia and the United States and how American policy approaches can be adapted and applied in Indonesia. It compares technical practices and also analyzes the legal and institutional dimensions of e-waste governance in both countries, and it formulates recommendations tailored to Indonesian conditions, including limited infrastructure and the predominance of the informal sector. In doing so, it addresses a gap in the literature on cross-national comparison between developing and developed countries in the field of e-waste, and it aims to provide an academic and advocacy reference for policymakers seeking to strengthen the national e-waste management system in a sustainable and evidence-based manner.

2. Method

This study employs normative juridical, or doctrinal, legal research, which focuses on the analysis of legal rules established in legislation and views law as a set of norms that direct social conduct toward what is deemed appropriate (Efendi & Ibrahim, 2018). The data were collected through library research and document review. The analysis combines a statutory approach, which examines the Indonesian and American instruments that bear on e-waste; a comparative legal approach, which sets these instruments side by side to identify differences in scope, institutional design, and allocation of responsibility; and a conceptual approach, which draws on the concepts of extended producer responsibility, hazardous waste, and legal transplantation to evaluate the findings and to frame recommendations. The comparison follows the functional method associated with Zweigert and Kötz (1998), which compares legal systems by asking how each responds to the same practical problem rather than by matching institutions that share a name. Applied here, the method treats the end-of-life management of electronic devices as the common problem and examines how each legal system defines e-waste, who bears responsibility for collecting and financing its management, which standards govern its processing, and which institutions supervise compliance. The functional method has well-known limits, since it may understate the cultural and institutional embeddedness of law, and the study therefore supplements it with the literature on legal transplants discussed in section 3.3.

3. Analysis and Discussion

3.1. Comparison of E-Waste Regulation in Indonesia and the United States

Despite considerable economic growth and a projected rapid increase in e-waste generation, e-waste remains a grey area in Indonesian law. Its generation is unevenly distributed because of the country's geo-economic conditions: Java is the primary source, contributing over 57% of the national total (Kurniawan, Soefihara, Nababan, & Kim, 2022). The estimated value of metals recoverable from Indonesian e-waste was USD 1.16 billion in 2021 and is projected to reach USD 1.84 billion by 2040 (Kurniawan

et al., 2022). Indonesia's low recycling rate, however, means that much of this value is lost (Kurniawan et al., 2022).

Regulation of e-waste remains limited, and the absence of comprehensive rules is one of the most significant challenges. Outside the industrialized nations, most developing countries still lack specific e-waste regulations. As of 2014, 61 countries, representing 44% of the global population, had adopted e-waste regulations (Shahabuddin et al., 2023); by 2019 the number had grown to 78 countries, representing 71% of the global population (Shahabuddin et al., 2023). Many countries still lack e-waste legislation and need to develop and enforce it, while those that already have it must strengthen it through regular and systematic updating. A further problem is the growth of illegal exports of e-waste to developing countries, particularly in Africa and Asia (Shahabuddin et al., 2023).

Recognizing the urgency and complexity of the issue, the Indonesian government has begun to regulate and supervise e-waste management. Among the instruments it has issued is the Regulation of the Minister of Environment and Forestry Number P.27/MENLHK/SETJEN/PLB.3/7/2020 on the Management of Non-B3 Waste from Household Electrical and Electronic Equipment, which sets out procedures for collecting, sorting, transporting, and recycling e-waste safely and sustainably. The regulation aims to build a sustainable e-waste management system that prevents environmental pollution, mitigates adverse health effects, and optimizes the recycling of reusable materials.

With appropriate management, e-waste that was once regarded only as a hazard can become a resource with economic value. Recycling allows numerous components, including precious metals, copper, and high-grade plastics, to be reused, which requires serious and collaborative effort from all parties in the interest of environmental sustainability and the future well-being of Indonesians. At present, however, the regulation of e-waste management in Indonesia is only implicit, distributed across six principal instruments.

Law Number 18 of 2008 on Waste Management serves as the foundation of the national waste management system. It directs government efforts to minimize waste generation, including e-waste, and emphasizes the 3R principle (reduce, reuse, recycle). Although it does not address e-waste specifically, it opens the way for more structured waste management, including stronger responsibility on the part of producers and communities for end-of-life electronic devices. Government Regulation Number 101 of 2014 on the Management of Hazardous and Toxic Waste is relevant because e-waste contains numerous hazardous and toxic substances, including mercury, lead, and cadmium, and is therefore classified as hazardous and toxic (*bahan berbahaya dan beracun*, B3) waste. The regulation governs the entire B3 waste cycle, from storage and transportation to disposal or recycling, and requires that this management be carried out by entities holding the requisite authorization so as to ensure safety and prevent environmental pollution.

Government Regulation Number 27 of 2020 on the Management of Specific Waste marks the government's first attention to categories of waste that require specific

handling, including e-waste. It affirms that such waste cannot be treated like ordinary household refuse and that appropriate technical and procedural strategies are needed to ensure that the processing of e-waste does not harm the environment or public health. Government Regulation Number 22 of 2021 on the Implementation of Environmental Protection and Management, which derives from Law Number 32 of 2009 on Environmental Protection and Management, addresses the management of hazardous and toxic waste and the control of environmental contamination, and in the context of e-waste it encourages responsible management by all parties on the basis of prudence and environmental responsibility.

At the technical level, Regulation of the Minister of Environment and Forestry Number 6 of 2021 on Procedures for the Management of Hazardous and Toxic Waste provides technical and administrative guidance, including procedures for waste identification, reporting systems, and technical standards for processing e-waste, and it emphasizes systematic and transparent management and compliance with established environmental standards. Regulation of the Minister of Environment and Forestry Number 9 of 2024 on Waste Containing Hazardous and Toxic Substances is among the most recent instruments and expressly identifies e-waste as a category of waste containing hazardous materials. It requires producers and consumers to reduce and handle e-waste through sorting, temporary storage, and transfer to licensed management agencies.

Read together, these instruments show the structural problem of Indonesian e-waste law. E-waste enters the legal system through two doors, as “specific waste” under the waste management regime and as hazardous waste under the environmental protection regime, and no single instrument defines it, allocates responsibility for it across its life cycle, or assigns producers a duty to take it back. The most recent ministerial regulation places duties on producers and consumers to sort and hand over e-waste, but it does not create the financing mechanism that EPR theory treats as the core of producer responsibility (OECD, 2016). The result is a regime in which obligations exist on paper while the collection channels that would make them effective remain informal.

In the United States, Allen Hershkowitz, a senior scientist at the Natural Resources Defense Council (NRDC), estimated that approximately 130,000 computers are discarded each day (Fehm, 2011). The EPA responded with the rule docketed as EPA-HQ-RCRA-2004-0012, titled “Hazardous Waste Management System; Modification of the Hazardous Waste Program; Cathode Ray Tubes; Final Rule” (Rahmadani, 2019). The rule was proposed on 12 June 2002 and took effect on 29 January 2007 (Rahmadani, 2019). Under this rule, one category of e-waste regulated in the United States comprises items containing PCB and CRT components (Rahmadani, 2019). E-waste in the United States originates from factories, households, the commercial sector, public facilities, and imported goods (Rahmadani, 2019), and all of it passes to intermediaries for recycling, landfilling, or export (Rahmadani, 2019). Under EPR policies, e-waste management has broadened to involve the federal government, state governments, local governments, private recyclers, and non-profit organizations. EPR makes producers responsible for their products after consumers have discarded them, and not only while consumers use them (Rahmadani, 2019). In some arrangements, the EPR system applies a fee to

consumers for the collection and recycling of used devices (Rahmadani, 2019). EPR assigns manufacturers responsibility for the complete life cycle of their products, including return, recycling, and final disposal (Smitty, 2015). Overall, the American strategy relies on collaboration and producer responsibility, but it continues to face challenges in policy uniformity and effective implementation at the national level.

Kahhat et al. (2008) explain the source of these challenges. They describe the American system as a patchwork in which the federal government regulates hazardous components such as CRTs while states legislate their own collection and financing schemes, and they propose a more integrated national system. The American model that Indonesia studies is thus itself contested at home: its strength lies in producer financing and in the experimentation that state autonomy allows, and its weakness lies in the absence of a uniform federal framework. This finding matters for the transplantation question raised in the introduction, since Indonesia, as a unitary state, can adopt national EPR rules directly and need not reproduce the fragmentation that the American federal structure has produced. The comparison is therefore asymmetric in an instructive way: Indonesia has the constitutional means to build the uniform national system that American scholars have recommended for their own country, but it has not yet built the producer-financed collection on which such a system depends, whereas the United States has built producer financing in many states without achieving national uniformity.

EPR policies aim to relieve governments of the financial and logistical burdens of waste management by transferring responsibility to the original producers or, in some cases, to the first importers of products, in accordance with the polluter-pays principle (OECD, 2016). The expected benefits include pollution prevention, greater waste diversion, fewer illegal exports, and resource recovery (OECD, 2016). EPR is also expected to give producers an incentive to design products with better life-cycle performance (Leclerc & Badami, 2023).

E-waste is the fastest-growing waste stream (Lundgren, 2012), and its effects on the environment and on human beings should prompt efforts to understand the consequences of improper handling and of different regulatory strategies (Lund, 2016). Institutionally, the United States addresses e-waste through the EPA, whose mission is to protect human health and the environment (U.S. Environmental Protection Agency, n.d.-b). The EPA developed the Alternative Disposition of Electronics Planning Tool (ADEPT), a modelling instrument that projects e-waste flows within states and evaluates management scenarios such as export and recycling (U.S. Environmental Protection Agency, n.d.-a). The purpose of comparing e-waste regulation in Indonesia and the United States is to improve the effectiveness of e-waste management in Indonesia, so that the government can develop effective rules on e-waste informed by the American experience.

Lund (2016) offers a way to read these institutional differences. Drawing on the tenets of the new environmental governance, he argues that e-waste is a poor fit for purely command-and-control regulation, because the waste stream is dispersed among millions of consumers, changes rapidly with technology, and crosses borders. Effective governance in his account combines binding rules with collaboration among public

agencies, producers, recyclers, and civil society, decentralized experimentation, and continuous monitoring and revision. The American arrangement displays several of these features: the federal rule sets a floor for hazardous components, states design their own collection and financing schemes, and the EPA supplies planning tools such as ADEPT that allow states and communities to compare scenarios. The Indonesian arrangement, by contrast, relies almost entirely on hierarchical instruments issued by the central government, while the actors who handle most e-waste in practice, namely households and informal collectors, have no defined place in the regulatory scheme.

Leclerc and Badami (2023) add a caution that applies to both countries. Studying Montréal, a city in a developed country with an operating EPR system, they found that a substantial share of e-waste still moves through informal channels outside the producer-financed system, and they conclude that EPR programmes must account for these flows if they are to achieve their circularity goals. If informal flows persist in a jurisdiction with mature EPR, they will dominate in Indonesia unless the regulatory design addresses them directly. The comparison therefore points to a conclusion that neither the Indonesian nor the American framework has yet fully drawn: the regulation of e-waste must govern the informal sector as an integral part of the system rather than treat it as a residual problem of enforcement.

3.2. Policy Recommendations for Indonesia Derived from the United States Framework

Indonesia faces a more complex situation than the United States, where producer responsibility systems operate across multiple states. Although several policies on hazardous waste already exist, Indonesia lacks explicit rules on e-waste management, and the relevant provisions are scattered across instruments such as Law Number 18 of 2008 on Waste Management and Government Regulation Number 101 of 2014 on the Management of Hazardous and Toxic Waste. These instruments need to be translated into active policies that allow e-waste recycling to contribute to output and employment while providing a safe and supportive working environment (Ghosh, 2011).

Low public awareness of the dangers of e-waste requires attention. The chemicals in e-waste can pollute groundwater and air and pose health risks, while processing facilities in Indonesia remain scarce. As a result, most e-waste is poorly managed: it is burned in the open or sold to scavengers who are unaware of the hazardous materials it contains, which exposes both the environment and informal workers to further harm.

Coordination among the central government, regional authorities, industry, and communities also remains weak, which produces uneven implementation across the country. In some regions, e-waste management still ranks as a low priority, even though the rapid advance of technology will intensify the problem. Indonesia, as a developing country with rising electronics consumption, therefore needs stricter and more comprehensive e-waste regulation that provides a firm legal foundation and protects both the public and the environment. On the basis of the foregoing analysis, such regulation should address five areas.

The first area is a definitive classification of e-waste (Kabul et al., 2024). Sorting, transportation, and processing all depend on a comprehensive classification of e-waste types, organized both by function, such as communication, entertainment, and household devices, and by the degree of hazard posed by the materials they contain. A clear classification would also close the gap identified above, in which e-waste enters the legal system through two separate doors without a unifying definition. In legal terms, the classification should specify when e-waste is treated as hazardous waste under Government Regulation Number 101 of 2014 and when it is treated as specific waste under Government Regulation Number 27 of 2020, so that collectors, transporters, and processors know which licensing and handling obligations apply at each stage. Without this specification, actors in the chain can neither comply nor be held to account, and supervisory agencies cannot determine which rules they are enforcing.

The second area is the implementation of an EPR system (Kabul et al., 2024). EPR encourages manufacturers to take responsibility for the life cycle of their products after their useful lives end by requiring them to provide collection, processing, and recycling facilities for the devices they produce. It can also motivate manufacturers to design products that are more environmentally friendly and easier to recycle, and consumer understanding and awareness of the system are crucial to its success (Agarwal, n.d.). The experience reported by Kojima et al. (2009) shows that an Indonesian EPR scheme must be designed around the informal sector rather than against it: where informal collectors pay households for discarded devices, a formal take-back system that offers consumers nothing will receive little e-waste. Producer financing should therefore fund collection points that buy from, or contract with, existing collectors, and the scheme should cover importers as well as domestic manufacturers in order to prevent free-riding.

The third area is the development of processing standards (Kabul et al., 2024). Regulation must include explicit and binding technical standards for the proper processing of e-waste, covering the separation of hazardous components, the treatment of heavy metals, and the safe disposal of residual materials. These standards may draw on international practices such as R2 certification or e-Stewards. Standards matter only if someone verifies compliance. The American experience shows that private certification schemes can supplement public inspection, since certified recyclers must submit to periodic third-party audits. Indonesia could make certification under a recognized scheme, or under an equivalent national standard, a condition for licensing facilities that process the hazardous fractions of e-waste. This would allow the Ministry to concentrate its limited inspection capacity on uncertified operators while giving producers a reliable list of facilities to which their EPR obligations can be discharged.

The fourth area is the legalization and recognition of brokers and collectors (Kabul et al., 2024). The informal sector, including collectors and scavengers, drives much of Indonesia's waste management. By legalizing and regulating its role, the government can ensure that collection and sorting take place safely and efficiently, and it should also provide training and employment security for these workers. Wilson et al. (2006) support this approach on the basis of comparative evidence from developing countries: informal recyclers achieve high recovery rates at low cost and provide livelihoods to the

urban poor, so that policies seeking to integrate them into formal systems tend to perform better than policies that seek to eliminate them. For e-waste, integration means confining the hazardous stages of processing to licensed facilities while allowing informal workers to continue in collection and manual dismantling under safer conditions.

The fifth area is the involvement of all stakeholders (Kabul et al., 2024). Effective e-waste management requires active participation: the government must set rules and incentives, producers must be accountable for their products, distributors and retailers must support collection systems, consumers must raise their awareness, and collectors must be integrated into the value chain. Cross-sector collaboration is essential. Collaboration of this kind requires information. The EPA's ADEPT tool rests on data about the volumes of e-waste generated, collected, and processed in each state, and Indonesia lacks comparable data at the regional level, as the reliance of current estimates on projections shows. A national e-waste regime should therefore oblige producers to report the quantities of electronics they place on the market and licensed facilities to report the quantities they receive and process. Such reporting would allow the government to measure collection rates, to set and revise targets, and to adjust the regime over time, which is the adaptive capacity that Lund (2016) identifies as central to effective environmental governance.

Technical solutions complement these legal measures. They include using components within the waste stream, selecting suitable e-waste feedstocks, developing simple and low-cost preparation processes, managing contaminants, and integrating techno-economic and life-cycle assessments. Concrete actions include reusing e-waste components as functional materials, selecting and processing e-waste to produce functional materials, managing contaminants while maximizing material reproducibility, and quantifying the environmental and economic benefits of materials derived from e-waste (Niu, Xiao, Xu, & Ruan, 2025). Recycling is preferable to landfilling and incineration because it is more environmentally sound (Ahmad, Qureshi, Rawat, Alkharisi, & Alturki, 2025).

E-waste is a global challenge that requires a progressive and inclusive policy response, and the development of sound recycling processes is crucial to mitigating it (Li, He, & Zeng, 2017). The American case shows that a decentralized approach centred on producer responsibility is feasible, although it still needs better coordination and supervision. Kahn-Freund's (1974) caution helps define what Indonesia should take from it: the principle of producer financing and the EPA's use of planning tools travel well, whereas the state-by-state fragmentation that reflects American federalism need not travel at all. Indonesia, which still lacks specific e-waste regulation, should therefore adopt a binding and comprehensive national policy, complemented by investment in infrastructure and public awareness. Given the significant environmental and health impacts of poorly managed e-waste, the government should treat the issue as part of its sustainable development agenda and as a test of its capacity to respond to contemporary challenges through forward-looking regulation.

3.3. Adapting the American Model: What Can and Cannot Be Transplanted

The recommendations above presuppose that elements of the American framework can operate in Indonesia. The comparative-law literature warns against assuming this. Watson (1974) famously argued that legal transplantation is the most fertile source of legal development and that rules move between systems with surprising ease. Kahn-Freund (1974) answered that the ease of transfer depends on how closely a rule is tied to the political and institutional environment in which it originated, and that rules bound up with a particular distribution of power travel poorly. Graziadei (2009) moves the debate beyond this opposition by treating transplantation as a process of translation in which the receiving system reinterprets the borrowed rule through its own legal knowledge, institutions, and actors, so that the rule that arrives is never identical to the rule that departed. For e-waste regulation, this perspective suggests asking which elements of the American model depend on features of the American context and which rest on principles that Indonesian institutions can absorb.

The principle of producer financing belongs to the second category. It rests on the polluter-pays principle, which Indonesian environmental law already recognizes, and on the economic observation that producers are best placed to reduce the costs of end-of-life management through product design (OECD, 2016). Indonesia can adopt it through national legislation without relying on any feature peculiar to the United States. The same is true of binding technical standards for processing, which can draw on certification schemes such as R2 and e-Stewards, and of planning instruments modelled on ADEPT, which require data and analytical capacity but no particular constitutional structure.

Other elements depend more heavily on context. The state-by-state structure of American EPR reflects a federal system in which states hold broad legislative authority over waste, and Kahhat et al. (2008) show that it has produced inconsistent coverage and duplicated costs. Indonesia, as a unitary state, has no reason to reproduce this fragmentation and can instead set a single national EPR framework, leaving regional governments to administer collection within it. Arrangements in which consumers pay a fee for the collection and recycling of used devices raise a different problem. In the United States, formal recyclers face little competition for discarded devices. In Indonesia, as Kojima et al. (2009) observed in China and Thailand, informal collectors pay households for their e-waste, so a scheme that charges consumers would drive devices toward the informal sector and starve formal facilities of feedstock. The financing should therefore fall on producers and importers at the point of sale rather than on consumers at the point of disposal.

The informal sector marks the deepest difference between the two contexts and the point at which translation, in Graziadei's sense, matters most. The American model presupposes that discarded electronics flow mainly through formal channels. In Indonesia, the informal sector performs most collection and much dismantling, and it supports livelihoods that a ban would destroy without improving environmental outcomes (Wilson et al., 2006). A translated EPR regime would use producer financing to purchase e-waste from informal collectors at registered collection points, license and train dismantlers, and reserve the hazardous stages of processing, such as the treatment

of CRT glass, circuit boards, and batteries, for licensed facilities. Such a regime would preserve the core principle of the American model while adapting its operation to the actors who handle e-waste in Indonesia, and it would give the obligations already contained in Ministerial Regulation Number 9 of 2024 a channel through which they could be fulfilled.

The analysis also clarifies the limits of what regulation alone can achieve. Kurniawan et al. (2022) estimate that the value recoverable from Indonesian e-waste will reach USD 1.84 billion by 2040, yet Indonesia's low recycling rate means that much of this value is lost. Recovering it requires processing capacity, and capacity requires a predictable supply of e-waste, which only a functioning collection system can secure. Producer financing, integration of informal collectors, and binding processing standards are therefore interdependent: each fails without the others. This interdependence explains why the scattered Indonesian instruments, each addressing a single dimension of the problem, have not produced an effective system, and why the reform proposed here takes the form of a single dedicated regime rather than further amendments to the general waste and hazardous waste laws.

4. Conclusion

The comparison answers the article's first question by showing a difference in legal architecture rather than merely in the quantity of rules. Indonesia regulates e-waste only implicitly, through Law Number 18 of 2008, Government Regulations Number 101 of 2014, 27 of 2020, and 22 of 2021, and Ministerial Regulations Number 6 of 2021 and 9 of 2024. These instruments classify e-waste either as specific waste or as hazardous waste, and none of them defines e-waste as a distinct category, allocates responsibility across its life cycle, or obliges producers to finance its collection. The United States, by contrast, combines a federal hazardous waste rule on cathode ray tubes, EPA-HQ-RCRA-2004-0012, with state EPR systems and EPA planning tools such as ADEPT. Its system is itself fragmented, but it places the financial burden of end-of-life electronics on producers, which the Indonesian framework does not do.

On the second question, the article argues that Indonesia should adapt the principle of producer financing while rejecting the fragmentation of the American model, and that it should design EPR around its informal sector. This conclusion follows from combining the comparative evidence with EPR theory and with the comparative-law literature on transplants. The article's contribution lies in this combination: earlier Indonesian studies recommended EPR by reference to developed-country practice, whereas the analysis here shows which elements of that practice depend on conditions Indonesia does not share and which can be transferred. The resulting design consists of a binding classification of e-waste distinct from household refuse; EPR obligations covering manufacturers and importers, with take-back systems that work with informal collectors; binding technical standards for processing, including the monitoring of emissions and residues and protection of occupational health; and the legal recognition of brokers, collectors, and scavengers, who already contribute substantially to waste reduction but work in unsafe and unprotected conditions. The comparison also reframes the debate about whether Indonesia lacks e-waste regulation. Indonesia does not lack

rules; it lacks a regime in which the rules on classification, financing, processing, and supervision connect with one another and with the actors who handle e-waste. The analysis has limits that such research should address. As a doctrinal study, it relies on the text of regulations and on secondary reports of their operation, and it cannot measure how much e-waste each channel actually handles or how producers and collectors would respond to particular financing rules. Further research should test this design empirically, in particular by examining how producer financing and informal collection interact in specific Indonesian cities and how the obligations of Ministerial Regulation Number 9 of 2024 operate in practice.

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