



Reduce, reuse, regulate: A comparative policy mix analysis of e-waste governance in five emerging economies

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ABSTRACT

Background: Rapid growth in electronic waste has led emerging economies to adopt complex regulatory arrangements. Research often examines individual laws or country-specific implementation, leaving interactions among instruments insufficiently understood. This study compares how national e-waste strategies and instruments operate within five emerging economies and how their policy mixes differ in consistency, coherence, and comprehensiveness. **Methods:** A qualitative comparative policy analysis used a Most Similar Systems Design (MSSD). Qualitative content analysis covered 23 national laws, regulations, and technical guidelines issued between 2008 and 2024 in China, India, Brazil, Ghana, and Indonesia. Scientific literature and Global E-waste Monitor data provided implementation context without determining legal coding or qualitative ratings. **Findings:** All five policy mixes showed medium consistency because targets, sanctions, incentives, and overlapping responsibilities remained imperfectly aligned. Coherence was high in China, India, and Brazil but medium in Ghana and Indonesia. Comprehensiveness was high in China and India, medium-high in Brazil, medium in Ghana, and low-medium in Indonesia. Subsidies, tradable certificates, and negotiated reverse logistics created organized constituencies for implementation. Municipal capacity and informal collection networks nonetheless shaped how national instruments operated locally. **Conclusion:** Regulatory maturity cannot be inferred from the number of adopted instruments. Effective urban e-waste governance requires aligned incentives, coordinated responsibilities across governmental levels, accessible collection, and integration measures that improve safety and livelihoods. **Novelty/Originality of this article:** The study extends policy-mix analysis by combining comparative regulatory assessment with Wilson's distributional typology and hybrid governance, linking formal policy design to the institutions through which e-waste moves.

KEYWORDS: electronic waste; emerging economies; extended producer responsibility; informal sector; policy mix.

1. Introduction

Rising consumption of electrical and electronic equipment has created waste faster than collection and recycling systems can manage it. In 2022, the world generated 62 million tonnes of e-waste, or 7.8 kg per person, yet only 22.3% was documented as formally collected and recycled in an environmentally sound manner (Baldé et al., 2024). Global e-waste volumes continue to rise faster than formal collection and recycling capacity, leaving valuable materials unrecovered and exposing workers and nearby communities to hazardous substances (Abalansa et al., 2021; Rautela et al., 2021). Emerging economies face a particularly difficult governance problem, as limited formal collection capacity often

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coexists with extensive informal handling and recycling (Abalansa et al., 2021; Shittu et al., 2021). These countries must therefore govern production, collection, recovery, and disposal as connected stages rather than isolated waste-management problems.

The need for a connected approach becomes most visible in cities. Municipal governments often provide collection sites, temporary storage, public information, and transport links between households and authorized recyclers, although national laws rarely assign these responsibilities uniformly (Leclerc & Badami, 2024). Effective delivery depends on clear municipal mandates, adequate financing, and coordination with producer organizations and national agencies. Informal collectors also move substantial volumes through repair, resale, dismantling, and markets for recovered materials across many emerging cities (Asibey et al., 2021; Dutta & Goel, 2021). Dependence on local arrangements explains why national legislation must be assessed as an interconnected governance system rather than a collection of formal obligations.

Governments have responded to these pressures with e-waste legislation, although legal coverage alone does not create an integrated system. National regimes commonly combine extended producer responsibility with take-back obligations, collection targets, and controls on recycling and treatment (Shittu et al., 2021). These instruments may reinforce one another, leave important stages uncovered, or impose conflicting obligations on the same actors. Policy-mix analysis therefore treats policy strategy, interacting instruments, and the processes through which they are designed and implemented as parts of one analytical object (Rogge & Reichardt, 2016). A substantial body of regulation can therefore remain ineffective when institutional responsibilities are unclear and the instruments fail to operate as a coherent system (Bahn-Walkowiak & Wilts, 2017).

Existing literature on e-waste often obscures interactions among instruments by presenting national regulations as separate policy measures. Prior studies clarify legal coverage and country-level implementation but offer limited insight into the alignment of national regulatory arrangements (Akon-Yamga et al., 2021; Arya & Kumar, 2020; Dias et al., 2022). Policy-mix analysis supports a broader assessment, although applications remain concentrated in European environmental sectors and rarely address relationships across governance levels (Castrejon-Campos et al., 2020; Di Santo et al., 2024). Formal rules in emerging economies also coexist with municipal, producer-led, and informal institutions, creating hybrid and polycentric governance arrangements (Banjongprasert, 2022; Dutta & Goel, 2021). Comparative research therefore leaves unresolved how e-waste instruments combine within these arrangements and how national mixes differ in consistency, coherence, and comprehensiveness across these countries.

This study systematically compares e-waste policy mixes in China, India, Brazil, Ghana, and Indonesia. All five are emerging economies with growing e-waste flows and persistent informal recycling, yet their regulatory systems differ markedly in maturity and instrument design (Baldé et al., 2024; Compagnoni, 2022). China and India have electronics-specific extended producer responsibility regimes, whereas Brazil organizes collective reverse logistics (Cao et al., 2016; Dias et al., 2022; Dutta & Goel, 2021). Ghana combines an import levy with take-back obligations (Faibil et al., 2023). Indonesia, by contrast, regulates e-waste within broader specific-waste and hazardous-waste frameworks (Rahmanda et al., 2023). Variation among these cases frames the central research question of how e-waste policy strategies and instruments interact within each country and how the five countries' policy mixes differ in terms of consistency, coherence, and comprehensiveness.

The study advances e-waste governance research by applying policy-mix theory to a field that commonly examines individual regulations or country-specific implementation. A shared framework makes five national arrangements directly comparable and provides a practical basis for policy redesign without treating legal adoption as evidence of an integrated system. The analysis moves beyond instrument counts to examine regulatory alignment, institutional coordination, lifecycle coverage, and the municipal, producer-led, and informal institutions operating alongside national regulation. Wilson's typology adds a political lens by clarifying how instruments distribute costs and benefits among regulated

actors and the wider public. Combining both perspectives connects formal policy architecture with the institutional and political conditions that shape implementation.

2. Methods

The study uses a qualitative comparative design to examine how e-waste policies are configured across China, India, Brazil, Ghana, and Indonesia. Comparative policy analysis enables systematic examination of national similarities and differences while preserving attention to their institutional contexts (Peters & Fontaine, 2020). The national e-waste policy mix serves as the unit of analysis and encompasses policy strategies, instruments, and governance and implementation arrangements. Within-country profiling traces how policy strategies and instruments interact. Cross-country comparison then assesses the consistency, coherence, and comprehensiveness of the resulting policy mixes.

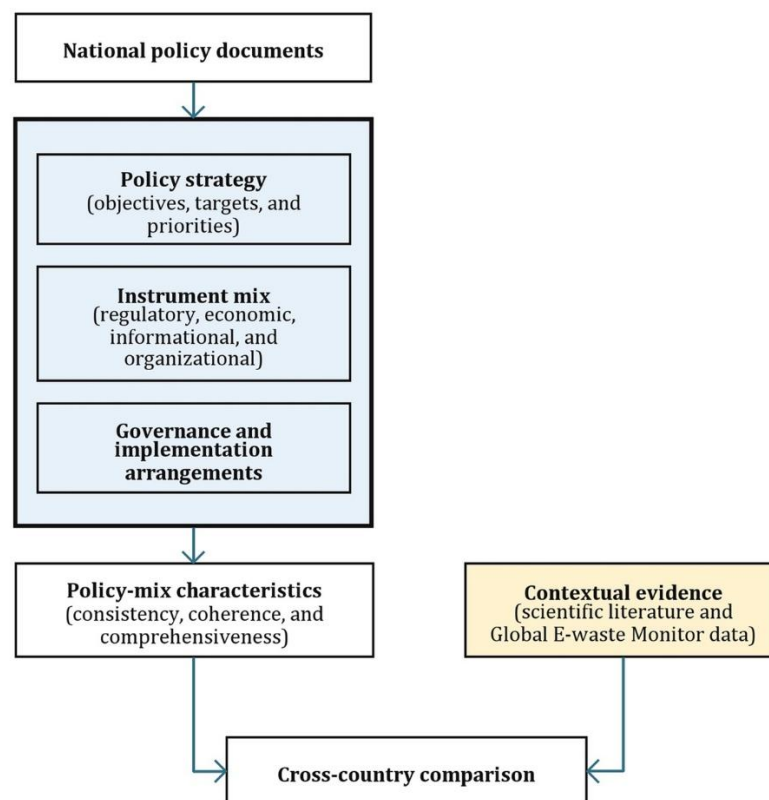


Fig. 1. Analytical framework for the comparative assessment of national e-waste policy mixes (Rogge & Reichardt, 2016; de Boon et al., 2021)

Figure 1 presents the analytical sequence used to construct and compare the five national policy-mix profiles. Primary policy documents are coded according to policy strategy, instrument mix, and governance and implementation arrangements. Each configuration is examined through consistency, coherence, and comprehensiveness, three policy-mix characteristics drawn from Rogge & Reichardt (2016) and previously applied comparatively by de Boon et al. (2021). Findings from the documentary analysis are consolidated into a standardized profile for each country before patterns, differences, gaps, and conflicts are compared across cases. Scientific literature and Global E-waste Monitor data provide contextual evidence and triangulation, but they do not alter the legal coding or independently determine the qualitative ratings. The formal profiles and ratings remained anchored in the coded national policy documents.

2.1. National policy strategies and instrument mixes

Table 1 summarizes the rationale for selecting China, India, Brazil, Ghana, and Indonesia. All five are emerging economies in which growing e-waste volumes, extensive informal activity, and weaknesses in enforcement or coordination complicate formal regulation (Abalansa et al., 2021; Compagnoni, 2022). Their regulatory approaches nevertheless vary from producer-financed EPR and certificate-based compliance to collective reverse logistics, import levies, and broader waste regulation (Akon-Yamga et al., 2021; Dias et al., 2022; Rahminda et al., 2023; Rai Bhardwaj & Chatterjee, 2026). Variation in regulatory design permits comparison of policy-mix characteristics across countries facing broadly similar governance problems. Case selection follows a broad most-similar logic rather than a strict variable-oriented MSSD intended for causal inference (Peters & Fontaine, 2020).

Table 1. Comparative rationale for case selection

Country	Distinctive regulatory orientation	Comparative value
China	State-led extended producer responsibility (EPR) and recycling-fund system	Mature combination of regulatory and economic instruments
India	Extended producer responsibility (EPR) targets and certificate-based compliance	Advanced formal design with implementation challenges
Brazil	Shared responsibility and collective reverse logistics	Negotiated and decentralized regulatory arrangement
Ghana	Eco-levy, take-back obligations, and import controls	Formal instruments operating alongside a dominant informal system
Indonesia	Broader hazardous- and specific-waste regulation	Emerging and comparatively limited national arrangement

The documentary corpus comprised 23 national instruments issued between 2008 and 2024: five from China, six from Indonesia, four from India, five from Brazil, and three from Ghana. Eligible materials had national scope and established e-waste responsibilities, targets, financing arrangements, administrative procedures, or technical requirements; superseded instruments were retained only to trace regulatory development. Documents were retrieved from official legal databases and government-agency websites, using official English versions where available and checking translated provisions against government summaries and peer-reviewed accounts. Drafts and unrelated instruments were excluded, while subnational materials were used only to interpret vertical coordination and urban implementation. Scientific literature and Global E-waste Monitor data provided additional context; Appendix A reports the complete inventory, retrieval sources, and legal-status checks completed on July 2026.

Following compilation of the documentary corpus, the instruments for each country were arranged chronologically to reconstruct regulatory development and identify the framework in force. Amendments were read alongside their parent regulations. Superseded instruments were retained only when they clarified a change in policy direction or institutional responsibility. Relevant provisions were then extracted under three layers: policy strategy, instrument mix, and governance and implementation arrangements. The extraction recorded product coverage and responsible actors. It also captured quantitative obligations, financing mechanisms, reporting duties, enforcement provisions, and the administrative level assigned to implementation. Country evidence was consolidated into standardized profiles that preserved links to the underlying legal provisions.

2.2 Comparative policy-mix characteristics

Table 2 guided a directed qualitative content analysis applied uniformly to all 23 documents, following de Boon et al. (2021). Relevant provisions were coded against four

indicators under each policy-mix characteristic. Strategy, instrument type, target group, and implementation setting were recorded to preserve differences among formally similar measures (Mavrot et al., 2019). Consistency covered relationships between strategies and instruments, interactions among instruments, and individual instrument design (Reichardt & Rogge, 2016). Coherence and comprehensiveness followed Rogge & Reichardt (2016), while standardized evidence matrices linked each country profile to specific documentary provisions (Li et al., 2020). Cross-country comparison used the completed profiles to identify alignments, conflicts, institutional gaps, and differences in coverage without attributing causal effects.

Table 2. Operational coding framework for e-waste policy-mix analysis

Dimension	Operational focus	Main indicators
Consistency	Alignment among policy elements	Quantitative target alignment; sanction alignment; incentive conflicts; regulatory and jurisdictional overlap
Coherence	Coordination of institutions and implementation processes	Horizontal coordination; vertical coordination; stakeholder participation; continuity of regulatory revision
Comprehensiveness	Breadth of the policy mix	Lifecycle coverage; actor coverage; instrument-type coverage; informal-sector integration
Contextual evidence (not scored)	Operation of formal arrangements	Collection; producer compliance; licensed recycling; enforcement; traceability; informal participation

(Rogge & Reichardt, 2016; de Boon et al., 2021)

Ratings were assigned after reviewing evidence across all four indicators rather than averaging scores mechanically. Borderline cases received the lower category when a missing core obligation or major institutional conflict weakened the dimension. Contextual sources could explain implementation conditions but did not override legal coding; missing information was recorded as insufficient evidence. Intercoder agreement was not applicable because coding was conducted by a single author. Credibility instead relied on a common codebook, a provision-linked evidence matrix, a second review of every country profile, and an explicit record of contradictory evidence. Reflexive attention was given to how the author's background in environmental policy and circular-economy research could emphasize formal regulatory alignment. Five categories guided the ratings: (1) High, indicating strong evidence across all or nearly all indicators, with no major contradictions; (2) Medium-high, indicating strong evidence across most indicators, but with one material gap remaining; (3) Medium, indicating mixed or partial evidence across indicators; (4) Low-medium, indicating weak evidence across most indicators, although one or two developed elements remain; and (5) Low, indicating little supporting evidence across the indicators.

3. Results and Discussion

3.1 National policy strategies and instrument mixes

Analysis of the 23 policy and regulatory documents produced comparable profiles of e-waste governance in China, India, Brazil, Ghana, and Indonesia. Results are organized in two stages. The first maps the strategies, instruments, and implementation arrangements constituting each national policy mix, while the second compares their consistency, coherence, and comprehensiveness. Primary legal provisions establish the formal content of each profile, with scientific literature and Global E-waste Monitor data providing context where implementation cannot be inferred from regulatory text alone. The combined

presentation then relates the cross-country patterns to policy-mix theory, informal recycling systems, and the distributional politics surrounding specific instruments.

Table 3. National E-waste policy strategies, instrument mixes, and implementation

Country	Policy strategy	Core instrument mix	Governance and implementation
China	State-led EPR linking product design, controlled recovery, and licensed treatment.	Producer and importer levy; WEEE treatment fund; subsidies for licensed recyclers; treatment licensing; reporting and sanctions; periodically revised subsidy standards.	National ministries coordinate regulation, while local authorities supervise licensed facilities. Informal collectors remain a major source of recovered products, particularly for categories not adequately covered by fund subsidies (Frantz Schneider & Zeng, 2022; Tian et al., 2022).
India	Quantified EPR administered through a national digital system and market-based compliance.	Producer and recycler registration; recycling targets; tradable EPR certificates; environmental compensation; reporting, auditing, and RoHS requirements.	The CPCB manages registration and certificate transactions, while state boards support enforcement. Formal recyclers and producer responsibility organizations continue to depend on informal collection networks that frequently retain material within informal processing channels (Gaur et al., 2025; Sengupta et al., 2022).
Brazil	Shared life-cycle responsibility implemented through collective reverse logistics for household electronics.	Mandatory collection points; phased collection targets; collective or individual reverse-logistics systems; <i>entidade gestora</i> communication plans; monitoring and reporting obligations.	Federal agencies oversee the system alongside industry organizations, retailers, and a performance-monitoring group. Waste-picker cooperatives may participate, although regional disparities, transport costs, and uneven formal-sector coverage constrain implementation (Ottoni et al., 2020; Frantz Schneider et al., 2026).
Ghana	Hazardous-waste control combined with import-based financing for national e-waste management.	Import eco-levy; Electrical and Electronic Waste Management Fund; importer registration; take-back obligations; deposit points; facility licensing; sanctions and technical guidelines.	The EPA, customs authorities, and an interagency fund structure lead implementation. A permitting route is available to informal operators, but no practical mechanism integrates their extensive collection and recycling networks into the formal system (Daum et al., 2017; Owusu-Sekyere & Aladago, 2023).
Indonesia	E-waste governance embedded within specific-waste and hazardous-waste regimes, with a general producer take-back obligation.	Producer take-back under Government Regulation No. 27/2020; hazardous-waste permits and treatment standards; municipal collection services; waste-bank channels. No electronics-specific fund, certificate market, quantitative target, or	Responsibilities are divided between national and local governments. Municipal schemes remain largely voluntary and geographically limited, while informal actors continue to control much of collection and material recovery (Rochman et al., 2017; Soesanto et al., 2022; Wibowo et al., 2021).

Country	Policy strategy	Core instrument mix	Governance and implementation
		published sectoral roadmap was identified.	

Note: CPCB = Central Pollution Control Board; EPA = Environmental Protection Agency; EPR = extended producer responsibility; RoHS = Restriction of Hazardous Substances; WEEE = waste electrical and electronic equipment; *entidade gestora* = management entity.

Table 3 shows that the five countries structure formal e-waste governance through distinct combinations of regulatory, economic, and organizational instruments. China finances subsidies for licensed recyclers through levies imposed on producers and importers (Tian et al., 2022). India uses quantified EPR obligations and tradable certificates under its current regulatory framework (Gaur et al., 2025). Its present system developed from an earlier transition between general hazardous-waste regulation and dedicated e-waste EPR (Garlapati, 2016). Brazil assigns shared responsibilities through negotiated reverse logistics (Frantz Schneider et al., 2026; Ottoni et al., 2020). Ghana combines an import eco-levy with take-back duties and a management fund (Daum et al., 2017; Faibil et al., 2023). Indonesia places producer take-back within broader waste regulation, although the analysis revealed no dedicated financing mechanism (Rahmanda et al., 2023).

Formal responsibilities extend below the national level in China, where State Council Order No. 551 places local environmental supervision within nationally defined recovery and treatment rules. India's E-Waste (Management) Rules 2022 divide administration among the CPCB, State Pollution Control Boards, and local bodies responsible for collecting orphaned products. Brazil's Decree No. 10.240/2020 organizes reverse logistics nationally and phases collection coverage according to municipal population and location. Ghana's L.I. 2250 permits District Assemblies to establish or facilitate collection centres and take-back systems. Indonesia's Government Regulation No. 27/2020 divides specific-waste responsibilities but does not establish a dedicated municipal e-waste system.

Urban evidence reveals how these formal arrangements operate under different local conditions. Delhi has licensed recycling facilities and collection services that receive e-waste from several states, positioning the city within a wider national flow (Dutta & Goel, 2021). In Accra, scarce municipal collection points and limited local capacity impede the integration of informal recycling into urban planning (Asibey et al., 2021). Jakarta has operated voluntary municipal collection since 2017 (Siringo et al., 2020) and formally recorded 33,289 kg in 2021 (Soesanto et al., 2022). Across metropolitan Rio, voluntary delivery points exist only in some municipalities and coverage requirements vary considerably (Ottoni et al., 2020). Chinese provincial evidence also finds subsidized formal facilities operating alongside dominant informal collection channels (Frantz Schneider & Zeng, 2022), exposing the problems that national policy inventories alone cannot reveal.

City-level variation does not constitute a separate outcome measure, but it clarifies how the three policy-mix characteristics become visible during implementation. Consistency is reflected in whether national targets and financing arrangements support locally accessible collection. Coherence appears in the links between national regulators and the organizations responsible for local delivery. Comprehensiveness depends on whether formal arrangements cover the actors and routes through which discarded electronics move, including informal networks. Urban evidence therefore provides context for the national comparison in Section 3.2 without independently determining the ratings or implying that policy design causes particular management outcomes.

3.2 Comparative policy-mix characteristics

Cross-country comparison moves beyond the presence of individual instruments to assess how each national configuration functions as a policy mix. Consistency captures whether targets, sanctions, incentives, and jurisdictional provisions support rather than undermine one another. Coherence concerns coordination across institutions and levels of government, stakeholder participation, and continuity in regulatory development, while

comprehensiveness evaluates coverage across lifecycle stages, actors, instrument types, and informal-sector integration. Ratings were assigned comparatively using the indicators established in Table 2 and the documentary evidence summarized in Appendix A. The resulting categories represent reasoned assessments of policy design and institutional arrangements, rather than quantitative measures of e-waste management effectiveness.

Table 4. Comparative assessment of national e-waste policy-mix characteristics

Country	Consistency	Coherence	Comprehensiveness
China	Medium. The product catalogue expanded beyond the five categories originally supported by Fund subsidies. Sanctions are consolidated and eco-design is legally required, although corresponding operational incentives remain limited.	High. Responsibilities are coordinated across national ministries and local authorities, supported by stakeholder consultation and successive regulatory revisions.	High. Regulation covers product design, recovery, treatment, financing, reporting, and a broad range of actors through regulatory, economic, and informational instruments. Informal-sector integration measures exist but remain limited in reach.
India	Medium. Recycling targets, EPR certificates, environmental compensation, and escrow arrangements broadly support the same objectives. Potential overlap with the Battery Waste Management Rules remains despite explicit exclusions and separate guidance.	High. Central administration through the CPCB is connected to state-level enforcement, public consultation, a national digital portal, and continued regulatory revision between 2016 and 2024.	High. Registration, storage, transportation, recycling, reporting, and hazardous-substance controls cover most lifecycle stages and regulated actors. Informal-sector formalization is recognized, although specific integration mechanisms remain limited.
Brazil	Medium. Phased targets, shared responsibilities, and financial compensation between participating entities are broadly aligned. Sanctions rely largely on general environmental provisions, although explicit clauses address regulatory overlap.	High. Federal agencies, industry representatives, and the performance-monitoring group coordinate implementation through a sectoral agreement and a staged municipal roadmap.	Medium–High. Reverse logistics covers consumers, producers, importers, distributors, retailers, management entities, and eligible waste-picker cooperatives. Upstream eco-design obligations and geographical coverage remain limited.
Ghana	Medium. Detailed sanctions and levy exemptions support the regulatory strategy, while a unified statute reduces jurisdictional overlap. No quantitative collection or recycling targets are established.	Medium. Interagency coordination and stakeholder representation are formally provided, but no clear vertical implementation structure was identified and regulatory development covers a relatively short period.	Medium. Regulation covers imports, financing, take-back, licensing, treatment, and disposal through several instrument types. Practical arrangements for integrating informal collectors and recyclers remain largely absent.
Indonesia	Medium. Explicit cross-references connect the specific-waste and hazardous-waste regimes, reducing regulatory overlap. Electronics-specific quantitative	Medium. Horizontal and vertical responsibilities are legally defined, and consultation is required during roadmap preparation. Evidence that an electronics-	Low–Medium. A broad legal definition and producer take-back obligation provide an initial foundation, but no dedicated financing mechanism, quantitative target, certificate system, or

Country	Consistency	Coherence	Comprehensiveness
	targets, sanctions, and economic incentives have not been established.	specific roadmap has been issued was identified.	has informal-sector integration not arrangement was identified.

Note: CPCB = Central Pollution Control Board; EPA = Environmental Protection Agency; EPR = extended producer responsibility; L.I. = Legislative Instrument.

Table 4 summarizes the assessment of consistency, coherence, and comprehensiveness across the five national e-waste policy mixes. Each characteristic captures a distinct quality of the policy mix and cannot be treated as interchangeable (Rogge & Reichardt, 2016). Broad regulatory coverage can coexist with conflicting instruments, and strong coordination can leave important actors or products unregulated. A medium rating records mixed evidence across the relevant indicators rather than partial achievement of an ideal system. No composite country score was calculated, so the profiles should be read as multidimensional assessments rather than a ranking of regulatory success.

Consistency first becomes visible in the relationship between quantitative obligations and the sanctions intended to secure compliance. India and Brazil establish measurable targets, but Brazil's phased requirement reaches only 17% of products placed on the market and India's obligations operate alongside persistent channelization problems (Gaur et al., 2025; Ottoni et al., 2020). China's expanded product catalogue is not matched by equivalent Fund coverage (Frantz Schneider & Zeng, 2022). Document coding found no collection target in Ghana and no electronics-specific target or clearly identified take-back sanctions in Indonesia. Regulatory stringency therefore varies, but no national mix fully connects the scale of its obligations to a complete and proportionate enforcement structure.

Consistency also depends on whether incentives reinforce regulatory duties and whether overlapping rules impose compatible requirements. China's levy-subsidy system directs funds to licensed recyclers, but persistent deficits and uneven subsidy coverage weaken competition with informal channels (Tian et al., 2022; Liu et al., 2022). India's certificate market directs compliance toward formal recycling despite competition for material, whereas Brazilian reverse logistics remains exposed to conflicting tax treatment (Sengupta et al., 2022; Frantz Schneider et al., 2026). Indian expert assessment nevertheless ranked an advance recycling fee as the least important management enabler, suggesting that an upstream fee may offer limited value when downstream collection and disposal responsibilities remain unresolved (Kumar et al., 2022). Ghana limits overlap through one unified statute, although Fund disbursement is not tied to take-back performance. Indonesia explicitly connects its waste regimes, but short storage permits, limited authorized processing capacity, and the absence of dedicated economic support may impede regional aggregation (Wirawan et al., 2019).

Moving from consistency to coherence shifts attention from compatibility among instruments to the institutional relationships through which policies are developed and administered. China and India show the strongest horizontal and vertical coordination. National regulators define each framework, and subnational authorities supervise facilities and enforce compliance. Brazil reaches a similar rating through interagency oversight and the Grupo de Acompanhamento de Performance, but implementation remains uneven across states and municipalities (Frantz Schneider et al., 2026; Ottoni et al., 2020). Ghana establishes interagency coordination under the EPA but lacks a clearly defined regional implementation structure. Indonesia distributes responsibilities across levels of government without an identified electronics-specific roadmap, showing that formal allocation alone does not ensure vertical coherence.

Stakeholder participation and regulatory continuity are evident in China through the consultation requirement under Article 7(3) of Order No. 551 and revisions extending to the 2021 subsidy standard. India documented a 60-day consultation before adopting the E-Waste (Management) Rules 2022 and continued adjusting the regime through amendments in 2023 and 2024. Brazil institutionalizes participation most clearly through the 2019 Sectoral Agreement and the performance-monitoring group established under Decree No.

10.240/2020, although participation remains centered on regulated industries (Ottoni et al., 2020). Ghana's Act 917 creates the Hazardous Wastes and Electronic Wastes Management Committee under Section 36, but the regulatory sequence has advanced little beyond LI 2250 and the 2018 Technical Guidelines. Indonesia requires stakeholder consultation for producer roadmaps under Article 13(2) of Government Regulation No. 27/2020, yet no electronics-specific roadmap was identified.

Policy comprehensiveness first becomes visible in lifecycle and actor coverage, with China regulating eco-design, recovery, licensed treatment, and disposal while assigning duties to producers, importers, collectors, sellers, and treatment facilities under Order No. 551. India similarly covers registration, storage, transportation, recycling, and reporting across manufacturers, producers, refurbishers, recyclers, and electronic retailers. Brazil extends reverse logistics from consumers to management entities and eligible waste-picker cooperatives, but its downstream orientation leaves eco-design and several producer or retailer responsibilities weakly specified (Nogueira et al., 2026). Ghana's framework spans imports, financing, take-back, treatment, and disposal, although broad formal actor categories have not produced substantial participation by informal operators (Owusu-Sekyere & Aladago, 2023). Indonesia combines a broad e-waste definition and producer take-back with hazardous-waste controls, yet upstream design duties and a dedicated collection architecture remain underdeveloped (Puluhulawa & Harun, 2024).

Beyond lifecycle and actor coverage, China combines regulatory controls with Fund subsidies and reporting requirements but only partly integrates informal collectors. India links targets and certificates to compensation and digital reporting but does not recognize kabadiwala networks as collection institutions (Sengupta et al., 2022). Brazil permits collective management and cooperative participation, but weak waste-picker involvement and irregular collection constrain domestic recovery (de Souza et al., 2016; Dias et al., 2022; Oliveira Neto et al., 2025). Ghana combines an import levy and dedicated Fund with permits and technical guidance yet informal labor remains governed outside the statutory mix (Nkansah-Dwamena, 2026). Analysis of Agboghloshie's 2021 demolition warns that simplified representations of informal e-waste activity can encourage displacement without resolving underlying urban and socioeconomic conditions (Grant et al., 2024). Indonesia relies on hazardous-waste permits and municipal collection, while household storage and established informal value chains remain beyond formal integration (Ardi & Handafiah, 2019; Rochman et al., 2017).

The comparison reveals that policy-mix maturity is multidimensional rather than cumulative. China and India combine high coherence and comprehensiveness with only medium consistency, showing that dense regulatory systems can still contain gaps between targets, subsidies, certificates, or adjacent rules. Brazil approaches the same level of institutional coordination but retains narrower lifecycle and geographical coverage, while Ghana and Indonesia rely on less developed arrangements with fewer operational links between legal duties and supporting instruments. Informal collection remains embedded in all five systems, even where formal actor coverage and enforcement structures appear extensive. The central comparative result is therefore not a simple ranking of regulatory strength: broader and better-coordinated mixes offer more complete governance architectures, but none fully aligns its instruments with the economic and institutional conditions through which e-waste is managed.

3.3 Discussion

This section interprets the comparative findings through the relationships among instrument design, regulatory politics, and informal governance. The comparative findings show that regulatory maturity is multidimensional rather than a linear progression toward a larger and more effective portfolio. China and India possess broad, coordinated arrangements but remain moderately consistent because successive reforms have not eliminated misalignments among product categories, targets, incentives, and adjacent

regulations. Brazil shows a similar tension at lower regulatory coverage. Ghana and Indonesia further demonstrate that unified legislation or formal coordination can coexist with missing operational instruments. Policy mixes often develop through layers of inherited objectives and procedures, which can expand coverage without resolving earlier contradictions (Migone & Howlett, 2024). Explaining the differences requires attention to how individual instruments distribute costs and benefits, create constituencies, and generate political support or resistance.

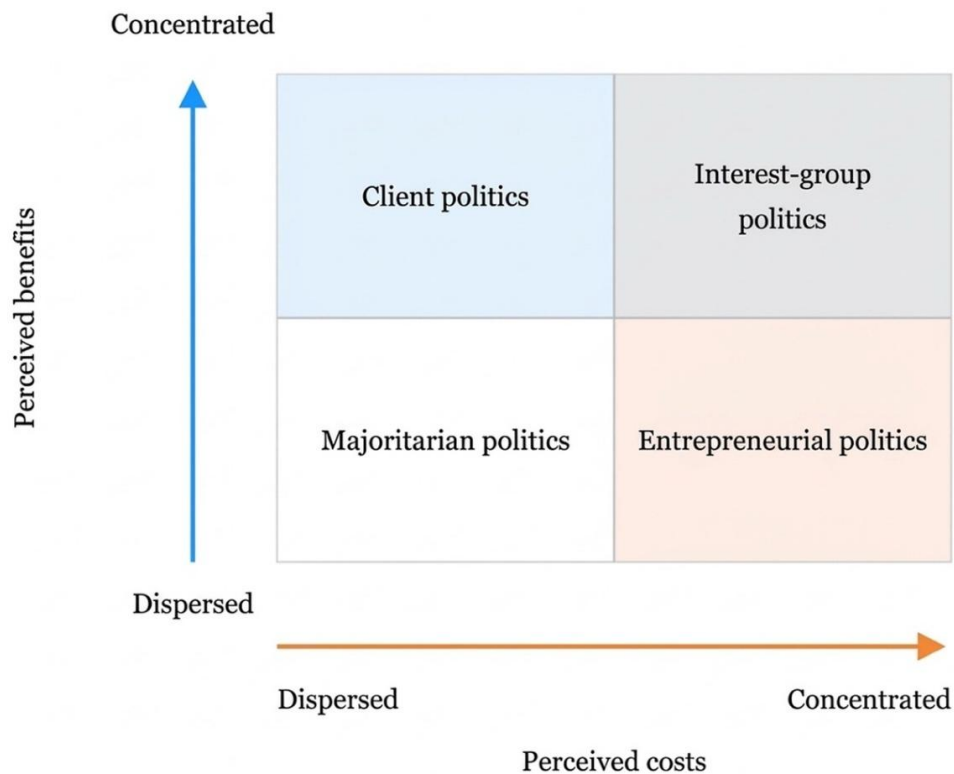


Fig. 2. Wilson's typology of regulatory politics
(Wilson, 1980)

Wilson's policy typology provides a framework for examining how the distribution of regulatory costs and benefits shapes political conflict. The framework distinguishes whether each is concentrated among identifiable actors or dispersed across the broader public (Wilson, 1980). Figure 2 combines the two dimensions into four configurations. Client politics grants concentrated benefits and spreads costs widely. Entrepreneurial politics reverses the distribution by imposing visible burdens on a regulated group in pursuit of diffuse public gains. Interest-group politics concentrates both costs and benefits, encouraging negotiation among organized actors. Majoritarian politics disperses both and moves debate toward public opinion, ideology, and electoral competition. The typology reveals who gains from an instrument, who bears its burdens, and which actors have sufficient incentive to support or oppose the implementation of e-waste regulation. It does not measure policy effectiveness or classify an entire country as a fixed political type.

Wilson's framework helps explain the constituencies formed by China's subsidy system and India's certificate market. China pools levies from producers and importers to subsidize licensed recyclers according to verified treatment volumes (Tian et al., 2022). Licensed facilities consequently acquire a direct stake in continued Fund operation. India allows registered recyclers to generate EPR certificates that producers need to meet quantified obligations, turning documented recycling into a tradable compliance asset (Gaur et al., 2025). Both arrangements concentrate benefits among formal recyclers and therefore display elements of client politics. Neither fits the category completely because producers

bear identifiable compliance costs rather than dispersed public costs. Informal competition in China and persistent channelization problems in India further limit the advantages created for registered recyclers (Liu et al., 2022; Gaur et al., 2025).

Other instruments produce different political configurations. Brazil concentrates compliance costs among producers and importers, which may organize collective reverse logistics through entities established for that purpose (Frantz Schneider et al., 2026; Ottoni et al., 2020). The Sectoral Agreement also gives regulated industries a formal role in negotiating implementation, giving the arrangement an interest-group tendency. Ghana combines an import levy, a management fund, and take-back obligations under its national framework (Daum et al., 2017; Faibil et al., 2023). The levy may disperse costs through electronics prices, and its environmental benefits are broadly distributed. Its design consequently approaches majoritarian politics, although the document analysis identified no organized beneficiary constituency with a durable interest in Fund enforcement. Indonesia's take-back duty resembles entrepreneurial politics because it concentrates producer costs and disperses environmental benefits (Rahmanda et al., 2023). No dedicated fund, certificate market, or collective management body was identified, and influential informal supply networks remain outside that institutional structure (Wibowo et al., 2021). The incomplete classifications point toward governance relationships that Wilson's distributional framework alone cannot explain.

A polycentric perspective addresses the limitation by examining the multiple decision centres through which e-waste governance operates. Polycentric governance treats overlapping authorities as a potentially coherent system rather than as evidence of institutional fragmentation. A coherent polycentric system depends on bridging organizations, recognized authority, accountability mechanisms, and adaptive law (Banjongprasert, 2022). Governance becomes hybrid when statutory rules coexist with informal networks that continue to organize collection and trade. Evidence from India shows that informal actors provide collection and dismantling services beyond the reach of formal facilities (Dutta & Goel, 2021). Municipalities introduce a further layer of governance. Evidence from Québec identifies program legitimacy and funding as important drivers of municipal participation. Logistical efficiency and transparency also shape collaboration (Leclerc & Badami, 2024). Policy coherence therefore depends on institutional relationships across governmental levels and between formal and informal actors.

Informal e-waste systems show why institutional relationships cannot be reduced to failures of compliance or enforcement. Ghana presents a case of "regulated informality". State officials apply rules selectively and work through local leaders even though such arrangements have no basis in Act 917 (Nkansah-Dwamena, 2026). India's kabadiwala networks form localized collection clusters that connect households with downstream traders and recyclers (Sengupta et al., 2022). Indonesia's five-level trading hierarchy likewise moves discarded electronics through successive levels of collectors and processors (Rochman et al., 2017). Recurring exchanges and recognized intermediaries give each network an internal order. Informal actors therefore function as organized institutions rather than isolated workers beyond regulatory reach. Treating them solely as enforcement targets can leave a formally coherent policy mix misaligned with the system that governs actual material flows (Lockwood et al., 2025).

The durability of informal e-waste networks stems partly from practical advantages that formal collection systems often fail to match. Fieldwork in Santiago identifies three advantages: agility, capillarity, and flexibility (Labra Cataldo et al., 2025). Agility enables workers to convert collected materials into income quickly. Capillarity develops through neighborhood networks that reach households beyond fixed collection points. Flexible schedules allow collectors to respond to changing material availability and immediate livelihood needs. Evidence from Santiago is geographically specific, but the mechanisms help explain the persistence of similar networks across emerging economies. Prohibition alone cannot replace their speed, reach, or adaptability. Integration should therefore preserve their collection capacity while improving occupational safety, labor protection, and material traceability.

Municipal governments provide the operational setting for integrating informal collection with formal treatment. The city evidence in Section 3.1 shows that national obligations depend on local capacity to connect households and collectors with authorized facilities. Municipalities can operate collection points and provide disposal information. They can also arrange temporary storage, contract local organizations, and document material transfers. Research on Québec's EPR system shows that funding, logistical efficiency, and transparency shape municipal participation (Leclerc & Badami, 2024). Evidence from Ghana similarly demonstrates how financial constraints and unclear institutional coordination can prevent national rules from shaping urban practice (Asibey et al., 2021). Clear mandates and cost-sharing arrangements are therefore necessary, but producer responsibility should finance local functions rather than transfer their costs to municipal budgets. National reporting cannot deliver traceability unless local collection systems first record where materials enter the formal chain.

Closing the gap between national reporting and local collection requires country-specific adjustments to each policy mix. China should align product-catalogue coverage with Fund eligibility so that all regulated devices face comparable recovery incentives. India needs to connect certificate transactions more directly to collection networks instead of concentrating compliance at the recycling stage. Brazil requires clearer allocation of collection and financing duties across producers, retailers, municipalities, and cooperatives. Ghana should link levy revenue to take-back performance and use the Fund to support safer participation by informal operators. Indonesia needs an electronics-specific roadmap that converts its general take-back duty into measurable obligations. Financing, reporting, and accessible local collection channels should form part of that roadmap. No single institutional model can address all five configurations; redesign must respond to the gaps within each national policy mix.

Comparable evidence outside the five cases shows how country-specific reform can be translated into institutional and financial mechanisms. Nigeria's 2022 framework increased producer registration but produced little improvement in informal collectors' incomes, safety, or formal engagement (Odeyingbo et al., 2025). Registration must therefore be paired with training and protective equipment. Financial incentives are also needed to make formal participation economically viable. Kala and Bolia (2024) examine India's broader urban waste sector rather than e-waste regulation. Their Delhi framework emphasizes community-level integration, explicit informal-sector inclusion, data-driven decisions, and regular policy review. Research from Metro Manila proposes premium buy-back payments and subsidized registration. Free protective equipment and cooperative organization form part of the same roadmap. Digital platforms would support fair pricing and traceability (Kudhal et al., 2026). Cooperatives could also distribute compliance costs and give informal workers a collective voice. Integration becomes credible only when compliance provides safer work, livelihood security, representation, and access to formal markets.

Concrete benefits must accompany any attempt to integrate informal collectors into formal e-waste systems. Registration alone can expose workers to new duties without improving income, safety, or access to recoverable materials. Financing and secure purchasing arrangements can make compliance economically viable. Training, protective equipment, and collective representation can reduce the risks of participation. The comparison also extends policy-mix analysis beyond the internal architecture of national regulation. Wilson's typology explains how individual instruments organize political support and opposition. Hybrid and polycentric perspectives reveal the decision centres operating alongside formal authority. Consistency, coherence, and comprehensiveness must consequently be evaluated against implementation in practice. Policy-mix quality ultimately depends on whether formal instruments align with the institutions that already determine how e-waste moves.

4. Conclusions

The study aimed to compare how national e-waste instruments operate as policy mixes and how their consistency, coherence, and comprehensiveness vary across five emerging economies (China, India, Brazil, Ghana, and Indonesia). The comparison concludes that policy-mix maturity is multidimensional rather than a linear accumulation of regulations. Broader and more coordinated portfolios may expand lifecycle and actor coverage without resolving misalignment among targets, incentives, sanctions, and jurisdictional responsibilities. Instrument design also shapes which actors acquire an organized interest in implementation, while formal arrangements remain conditioned by informal and parallel governance systems. Applying the three characteristics across emerging economies advances policy-mix scholarship by showing that regulatory integration must be assessed through relationships among instruments, institutions, and existing material-flow networks rather than legal density alone.

However, the contribution remains bounded by the study's documentary design. National laws and regulations reveal formal policy architecture but cannot establish how consistently instruments are implemented or enforced. Comparable implementation evidence was uneven across the five countries. Subnational material was therefore used only as context rather than as a basis for ratings. The qualitative categories represent structured interpretations of documentary evidence, not numerical measures of performance. Case selection also limits generalization beyond the five emerging economies examined. Future research should combine document coding with stakeholder interviews and comparable material-flow or compliance data. Longitudinal research at the city level could show how municipal capacity, informal-sector participation, and enforcement practices alter national policy mixes over time. Such evidence would test how the relationships identified here operate in practice.

The study's practical contribution concerns the urban institutions that turn national obligations into collection and recovery. Additional legal duties will have limited value unless financing and traceability are connected with accessible collection and clearly assigned responsibilities. Municipalities need defined mandates and reliable support from producer-financed systems so that local services do not absorb unfunded obligations. Informal collectors need safe routes into formal markets that protect livelihoods and recognize their knowledge of existing recovery networks. Better coordination can reduce hazardous leakage and broaden participation in municipal waste systems. Aligning formal instruments with existing recovery institutions and livelihoods is what turns e-waste regulation into a functioning part of sustainable urban governance.

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Author Contribution

Conceptualization, N.A.A.; Methodology, N.A.A.; Validation, N.A.A.; Formal Analysis, N.A.A.; Investigation, N.A.A.; Resources, N.A.A.; Data Curation, N.A.A.; Writing – Original Draft Preparation, N.A.A.; Writing – Review & Editing, N.A.A.; Visualization, N.A.A.; and Project Administration, N.A.A. The author has read and approved the submitted version of the manuscript.

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Conflicts of Interest

The author declares no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the author used Anthropic Claude and OpenAI Codex to assist in organizing policy evidence, developing preliminary comparative tables and figures, outlining the manuscript, and improving grammar, clarity, and academic tone. The author subsequently reviewed the cited sources, verified the regulatory evidence and interpretations, edited the generated content as needed, and takes full responsibility for the content of the publication.

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