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IMPLEMENTING EXTENDED PRODUCER RESPONSIBILITY (EPR) FOR ELECTRONICS IN THE U.S.: A COMPARATIVE ANALYSIS OF STATE-LEVEL POLICIES AND BEST PRACTICES FOR NATIONAL HARMONIZATION

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ABSTRACT

This review synthesizes evidence on state-level Extended Producer Responsibility (EPR) programs for electronics in the United States and identifies pathways toward practical national harmonization. Drawing on policy reports, program evaluations, and comparative analyses through 2016 to 2025, the paper maps the current policy landscape, characterizes core design choices (product scope, financing, performance metrics, enforcement), and evaluates observed outcomes in collection, material recovery, economic efficiency, and stakeholder engagement. This review reveals that while state EPR programs outperform ad hoc municipal systems on documented collection and diversion, performance and implementation are highly heterogeneous: states differ markedly in what devices are covered, how programs are funded (point-of-sale fees, producer-funded schemes, or hybrids), and how results are measured and enforced. Quantitatively, 25 states and the District of Columbia now have statewide e-waste laws. 23 of those rely on manufacturer-funded EPR models, while California continues to use an advanced, point-of-sale recycling fee—an inconsistency that complicates compliance for national producers and undermines cross-state comparability of hazardous-material outcomes. This inconsistency imposes administrative burdens on national producers, complicates cross-state comparisons, and undermines consistent hazardous-material management. High-performing programs are characterized by several features, such as clear statutory scope, stable financing (often through producer responsibility organizations), centralized plan approval or registries, verifiable reporting, and explicit convenience standards for collection. These together improve uptake and accountability. The review recommends pragmatic harmonization strategies that preserve state innovation: interoperable reporting templates, phased federal baselines for performance and oversight, a national clearinghouse or registry, targeted technical assistance, and structured multi-stakeholder governance.

KEYWORDS: *Extended Producer Responsibility (EPR), Electronic Waste Management, State-Level Environmental Policy, Producer Accountability, Policy Harmonization, Recycling Infrastructure, Circular Economy*

I. INTRODUCTION

Electronic waste (e-waste), broadly defined as discarded electrical or electronic devices, has become one of the fastest-growing waste streams worldwide, driven by rapid product turnover, shorter device lifespans, and accelerating global consumption of consumer electronics (Forti et al., 2020). Global e-waste is rising rapidly from 62 million tonnes in 2022 and, at an average increase of about 2.6 million tonnes per year, it is projected to reach roughly 82 million tonnes by 2030 (Global E-waste Monitor, 2024), underscoring the urgency of more robust and harmonized EPR policy interventions. As shown in Figure 1, state-level collection trends in California and Washington demonstrate how mature EPR programs have sustained significant diversion volumes over time, reinforcing the need for harmonized national strategies. Recent assessments indicate that global e-waste volumes rose sharply in the early 2020s and that the fraction of e-waste documented as collected and properly recycled remains low and, in some projections, may decline if current trends persist (Baldé et al., 2024). In recent years, the United States has generated millions of tons of consumer electronics waste annually, much of which is managed through municipal solid waste systems (U.S. EPA, 2016; Baldé et al., 2024). Although the waste stream is substantial, notable gaps exist in documentation, collection, and recovery. Persistent governance and data gaps also enable undocumented export flows and weaken oversight (Norgbey & Cudjoe-Mensah, 2025). These shortcomings result in the loss of valuable recoverable materials and the improper disposal of hazardous components, which frequently end up in landfills, incinerators, or informal recycling operations (Rawat et al., 2024; Baldé et al., 2024). The disposal of electronic waste through landfilling, incineration, and

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informal recycling pathways presents significant environmental and public health risks. Hazardous constituents commonly found in electronic devices, such as lead, mercury, brominated flame retardants, and organic pollutants can leach into soil and water systems, degrade air quality, and pose serious health threats to exposed populations (Rawat et al., 2024).

In response to the growing environmental and economic challenges associated with electronic waste, policymakers in the United States have increasingly adopted regulatory instruments that shift end-of-life management responsibilities upstream. Major electronics brands, such as Apple and Dell, operate voluntary take-back and recycling programs that complement state EPR mandates. EPR frameworks assign producers financial and organizational accountability for the post-consumer phase of products they introduce to the market. These frameworks aim to enhance collection and recycling rates while fostering design innovations that support circular economy principles (Campbell-Johnston et al., 2023). In the United States, the application of EPR policies has been characterized by a fragmented approach. This fragmentation introduces legal complexities (varying statutory definitions), operational challenges (different reporting formats), and fiscal burdens (duplicated compliance costs) (OECD, 2024). A growing body of empirical and review literature indicates that well-structured EPR programs can enhance collection rates, stabilize recycling supply chains, and incentivize improvements in product design. However, the effectiveness of these programs is highly contingent upon the quality of their design, governance structures, producer obligations, performance benchmarks, and enforcement capacity. These findings underscore the relevance of EPR as a strategic policy instrument in ongoing debates surrounding electronic waste governance in the United States (Campbell-Johnston et al., 2023).

Despite its conceptual promise, the implementation of EPR in the United States is marked by considerable heterogeneity. Variations in legal scope, definitions of covered products, financing and reporting mechanisms, and the roles assigned to producers, municipalities, and oversight bodies have led to disparate policy landscapes. As a result, state-level EPR laws and programs differ significantly in coverage and operational detail, contributing to disparities in performance outcomes, cost structures, and stakeholder experiences (OECD, 2024). The inconsistent nature of EPR implementation across U.S. states presents significant operational and strategic challenges. National producers must navigate a complex and often inconsistent regulatory landscape, incurring elevated compliance costs and administrative burdens. Municipalities and recyclers face divergent obligations and funding mechanisms, while broader national goals, such as material security, equitable access to recycling services, diversion targets, and incentives for repair-oriented design remain difficult to align without coherent cross-state coordination. Academic analyses highlight that regulatory fragmentation not only imposes economic inefficiencies but also undermines policy effectiveness, reinforcing the need for harmonized frameworks that balance national coherence with state-level innovation (Lifset et. al., 2023).

The purpose of this literature review is to synthesize the extant evidence on state-level EPR policies for electronics in the United States and to identify theoretical and practical pathways toward national harmonization. Specifically, the review will (1) map the landscape of U.S. state electronics EPR statutes and program designs; (2) assess empirical and evaluative studies on outcomes (collection, recycling rates, costs, market impacts, design incentives); and (3) interrogate governance, legal, and implementation challenges that shape transferability and scalability across states. Building on a rigorous and comparable evidence base from policy reports, peer-reviewed evaluations, and systematic reviews published from 2016 to 2025, the review aims to highlight design features that significantly affect performance, tradeoffs inherent in harmonization strategies, and research gaps that should guide subsequent evaluation and legislative efforts. This literature-based synthesis provides a basis for developing evidence-based, actionable recommendations for how state efforts can be standardized and what the potential shape of an integrative, nationally interoperable EPR framework specifically for electronics in the US could look like.

II. THEORETICAL FOUNDATIONS OF EPR

EPR is grounded in a set of normative and economic principles that associate environmental accountability with those who derive benefit from the production and sale of goods. Fundamentally, EPR serves as a mechanism for operationalizing the Polluter Pays Principle (PPP), by reallocating financial and, in some cases, organizational responsibility for end-of-life product management from municipalities and consumers to producers. This shift is intended to internalize environmental costs and incentivize more sustainable product design and lifecycle management (Ghulam & Abushammala, 2023). PPP provides the ethical and economic foundation for assigning producers financial responsibility for the disposal and remediation of environmental harms associated with their products. By internalizing life-cycle costs, PPP ensures that environmental externalities are reflected in market transactions, thereby incentivizing more sustainable production and consumption practices. EPR schemes serve as a practical mechanism for implementing PPP by shifting end-of-life management obligations upstream to producers (Campbell-Johnston et. al., 2023). Empirical and policy literature increasingly emphasize that EPR, when implemented as more than a basic waste management fee, can serve as a strategic tool to align producer incentives with environmental objectives. Specifically, well-designed EPR schemes, particularly those incorporating eco-modulation can encourage producers to reduce the environmental impacts of product design and supply chains by internalizing lifecycle costs and rewarding sustainable practices (Lifset et al., 2023). Hybrid arrangements combine mandatory producer financing with voluntary operational control, often mediated through Producer Responsibility Organizations (PROs).

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The lifecycle responsibility concept embedded in EPR frameworks expands producer obligations across all stages of a product's existence, from design and manufacturing through distribution, use, and post-consumer management. This approach draws on life cycle thinking in environmental policy and encourages "design for environment" strategies, such as disassembly, reparability, and material recovery, thereby reducing downstream treatment and recycling costs through upstream interventions (Lifset et al., 2023). By treating the product lifecycle as the central unit of governance rather than focusing solely on discrete waste endpoints, EPR reframes environmental management as a continuous, systemic process.

From a policy perspective, this lifecycle framing transforms end-of-life management into a mechanism for design feedback and innovation. It incentivizes upstream interventions, such as design for disassembly, reparability, and material recovery that lower downstream costs and environmental impacts, thereby reinforcing circular economy objectives and aligning industrial practices with sustainability transitions (Campbell-Johnston et al., 2023; Baldé et al., 2024).

Cost internalization is the principal mechanism through which EPR operationalizes both the Polluter Pays Principle (PPP) and lifecycle responsibility. By embedding end-of-life management costs into producer pricing structures or producer-funded systems, EPR ensures that market signals reflect environmental externalities that would otherwise be borne by local governments or ecosystems. Recent policy analyses and empirical reviews outline a spectrum of internalization approaches, including deposit-refund systems, eco-modulated fees, producer responsibility organizations (PROs), and direct take-back obligations, each with distinct implications for pricing dynamics, administrative complexity, and potential cost pass-through to consumers (Parvez et al., 2021; OECD, 2024). Critically, academic literature warns that when EPR is implemented primarily as a funding mechanism, focused on fee collection without granting producers operational control or embedding design incentives, its potential to drive circular product innovation and reduce overall system costs may be significantly compromised. Such limited frameworks risk treating EPR as a compliance obligation rather than a strategic tool for environmental design reform, thereby undermining its effectiveness in advancing circular economy objectives (Ghulam & Abushammala, 2023).

From a policy-rationales perspective, three theoretical strands commonly justify EPR in academic literature. First, environmental economics provides a classical market-failure argument: EPR serves to correct negative externalities and internalize social costs through targeted regulatory instruments, thereby enhancing allocative efficiency. This rationale positions EPR as a mechanism for aligning private decision-making with broader societal and environmental objectives (OECD, 2024). Second, EPR is conceptualized as a mechanism for closing material loops by enhancing product collection and recovery, and by incentivizing design choices that preserve material value. This approach supports resource efficiency and contributes to the decoupling of consumption from virgin resource extraction, hence advancing sustainability objectives within product systems (Linnell et al., 2016). Third, EPR is increasingly recognized as a hybrid policy instrument that reconfigures the distribution of roles between public and private actors. Hybrid arrangements combine mandatory producer financing with voluntary operational control, often mediated through Producer Responsibility Organizations (PROs). It facilitates the redistribution of operational responsibilities among producers, municipalities, and producer responsibility organizations (PROs), mandates new information flows such as reporting and traceability, and supports the development of performance-based regulatory frameworks. These frameworks emphasize measurable outcomes and enforcement mechanisms over prescriptive rules, as a result, enhancing accountability and adaptive governance (OECD, 2024). Collectively, these rationales demonstrate that EPR serves as a multifaceted instrument, concurrently addressing economic inefficiencies, fostering circularity, and driving governance innovation. Comparative global models serve as both theoretical and practical benchmarks for the design of EPR frameworks. The European Union's Waste Electrical and Electronic Equipment (WEEE) directive, particularly its 2018 recast and subsequent clarifications exemplify a legally codified, target-driven EPR regime. It integrates collection and recycling targets, reporting obligations, and producer take-back responsibilities, as such institutionalizing lifecycle responsibility at a supranational scale. However, empirical studies reveal trade-offs in compliance complexity and heterogeneous implementation across member states, underscoring the challenges of harmonizing regulatory frameworks while preserving national flexibility (Forti et al., 2020). Canada's provincial EPR systems, exemplified by programs administered through PROs such as the Electronic Products Recycling Association (EPRA) illustrate a federated governance approach in which sub-national regulations define producer obligations and market structures tailored to local contexts. These systems offer valuable insights into plan approval processes, producer coordination mechanisms, and operational oversight strategies. Complementing these national experiences, Organization of Economic Cooperation and Development (OECD) guidance documents provide widely referenced conceptual and practical templates that define EPR's objectives, typologies, and governance safeguards, serving as benchmarks for the design and evaluation of national or multi-jurisdictional frameworks (OECD, 2024). These models elucidate the theoretical underpinnings of institutional design decisions, including targets, financing mechanisms, producer responsibility organization roles, and fee structures, while highlighting inherent tensions that must be navigated in pursuing U.S. national harmonization.

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Table 1. Comparison of International EPR Models for Electronic Waste

Dimension	European Union - WEEE Directive (2018 Recast)	Canada - Provincial EPR (e.g., EPRA Model)	OECD Guidance Framework (2024)
Governance Structure	Supranational directive with national transposition; harmonized minimum requirements but varied implementation across Member States.	Decentralized provincial authority; Producer Responsibility Organizations (PROs) operate under provincial regulations (e.g., EPRA).	Non-binding policy framework offering principles and best practices for national EPR design.
Financing Mechanism	Producer-funded through take-back obligations and compliance schemes; fees often modulated by product characteristics (eco-modulation).	Producer-funded, typically through PRO-administered fee structures; cost recovery tailored to provincial market conditions.	Outlines cost internalization principles and encourages fee modulation aligned with lifecycle impacts.
Product Scope	Defined categories under "open scope," covering most electrical and electronic equipment placed on the market after 2018.	It varies by province; generally, includes major electronics (TVs, computers and peripherals, small appliances)	Recommends a comprehensive scope covering full device lifecycle and emerging product categories.
Performance Targets	Legally binding collection and recovery targets; reporting required at EU and Member State levels.	Targets set at the provincial level; some require PROs to demonstrate collection coverage or recycling rate achievements.	Does not impose targets but provides design principles for establishing performance measurement systems
Compliance and Enforcement	National enforcement authorities monitor producer registration, reporting, and attainment of collection and recovery targets	Provinces oversees compliance; PROs required to submit stewardship plans and annual performance report	Emphasizes transparency, monitoring protocols and enforcement mechanisms as essential governance safeguards
Producer Responsibility Organization (PRO) Role	PROs manage collective compliance for producers; vary by Member State in scope and independence.	PROs (e.g., EPRA) centrally administer collection networks, contracts with processors, and reporting requirements.	Provides conceptual guidance on PRO governance, performance accountability, and fee-setting transparency.
Strengths	Harmonized minimum standards; high collection and recovery benchmarks; strong data reporting systems.	Flexible provincial adaptation; coordinated producer participation; well-developed collection infrastructures.	Universal applicability; establishes best-practice benchmarks and governance models for emerging EPR systems.
Challenges	Implementation gaps across Member States; administrative burden on cross-border producers.	Fragmented provincial variations; varying stringency and enforcement capacities.	Does not mandate compliance; effectiveness depends on national adoption and adaptation.

III. STATE-LEVEL EPR POLICIES FOR ELECTRONICS IN THE U.S.

State-level EPR programs for electronics in the United States have evolved into a mature yet highly heterogeneous policy landscape. These programs encompass a mix of long-standing manufacturer-funded take-back schemes, point-of-sale fee structures, and more

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recent producer-organized systems. Two dozen states and the District of Columbia have passed electronics EPR laws or producer-responsibility frameworks as of recent inventories. This has resulted in a decentralized array of obligations and operational models that vary significantly in terms of covered products, funding approaches, performance metrics, and enforcement mechanisms (Campbell-Johnston et al., 2023).

Overview of Existing Policies

California, Washington, and New York exemplify three distinct approaches to state-level EPR for electronics. California's Covered Electronic Waste (CEW) program, established under the Electronic Waste Recycling Act of 2003 and expanded through subsequent legislation, operates through a point-of-sale recycling fee system. Retailers collect fees from consumers at the time of purchase and remit them to the California Department of Tax and Fee Administration (CDTFA), which funds the state's collection and recycling infrastructure for covered electronic devices. This model supports the recovery of large, screened devices and certain battery-embedded electronics, and is administered collaboratively by CalRecycle, CDTFA, and the Department of Toxic Substances Control (DTSC) (CalRecycle, 2025).

Washington State administers the E-Cycle Washington program, a manufacturer-funded initiative that mandates producers of covered electronic products, such as televisions, computers, and monitors to register annually, pay administrative fees, and participate in a comprehensive recycling plan. This program ensures free, convenient, and environmentally responsible recycling for residents, small businesses, and other eligible entities. Since its inception, E-Cycle Washington has successfully diverted millions of pounds of electronic waste from landfills, with recyclers adhering to stringent performance standards set by the Department of Ecology. (Washington State Department of Ecology, 2025)

Similarly, New York State enforces the Electronic Equipment Recycling and Reuse Act, which places EPR on manufacturers of covered electronic equipment. The law requires manufacturers to offer free and convenient recycling options to most consumers, submit annual reports, and engage in public education efforts. The New York State Department of Environmental Conservation oversees compliance and supports collective electronic waste acceptance programs to meet statutory obligations (NYSDEC, 2024). These policy exemplars illustrate the diversity of regulatory frameworks employed across U.S. states to manage electronic waste, including retailer-imposed fee structures, producer-funded take-back mandates, and manufacturer registration and compliance regimes.

Table 2: ***Comparison of State-Level Extended Producer Responsibility (EPR) Approaches for Electronics***

State	Program name / year	Funding mechanism	Administering agencies	Key features	Coverage and outcomes
California	Covered Electronic Waste (CEW) Program / 2003	Point-of-sale recycling fee collected by retailers	CalRecycle; CDTFA; DTSC	Retailer fee system; funds statewide recycling infrastructure	Covers large-screen and battery-embedded devices; sustained collection and recycling network
Washington	E-Cycle Washington / 2009	Manufacturer-funded	Washington Department of Ecology	Mandatory producer registration and recycling plan; free recycling	Millions of pounds diverted from landfills; recyclers meet strict performance standards
New York	Electronic Equipment Recycling and Reuse Act / 2010	Manufacturer responsibility (take-back system)	NYS Department of Environmental Conservation (NYSDEC)	Free recycling for consumers; annual reporting; public education	Broad statewide access through collective acceptance programs; compliance-based monitoring

Note*. This table summarizes three U.S. state-level EPR frameworks for electronic waste management. Sources: CalRecycle (2025); Washington State Department of Ecology (2025); NYSDEC (2024).*

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Policy Design Elements

State e-waste policy design shows wide variation across four core dimensions that shape program outcomes and costs. First, product scope differs markedly; some states target only major video displays while others include small electronics, servers, and battery-embedded devices, shaping collection infrastructure and processing needs. Second, financing models range from point-of-sale consumer fees to producer-funded systems and hybrid cost-shares, each with distinct implications for incentives and administration. Third, performance monitoring is uneven: jurisdictions report different metrics, such as total weight, per-capita collection, diversion rates, complicating cross-state comparison. Finally, enforcement regimes and oversight capacity vary, influencing compliance rigor. These design choices reflect trade-offs between simplicity, adaptability, and equity, and create practical compliance complexity for producers operating across states.

Product Scope

States differ considerably in the scope of electronic devices classified as 'covered' under their respective recycling statutes. California's Covered Electronic Waste (CEW) program, established under the Electronic Waste Recycling Act, primarily targets devices with video displays exceeding four inches and has recently been amended to include battery-embedded products, reflecting evolving product designs and disposal challenges (CalRecycle, 2025). In contrast, Washington and several other states typically include computers, monitors, and televisions as standard-covered devices. Some jurisdictions, such as New York and Illinois, explicitly extend coverage to small electronic equipment, servers, and peripherals, demonstrating broader statutory definitions of electronic waste (Linnell et al., 2016).

The scope of devices designated as 'covered' under state electronics recycling laws significantly influences the infrastructure required for collection and the associated costs of recycling. Device complexity, such as the presence of embedded batteries, composite materials, and hazardous components, varies widely across categories, consequently affecting processing requirements and cost structures. A recent study by Quinto et al. (2025), grounded in a comprehensive global literature review, detailed case studies (including the Recykal system in India), and a decision-support modelling framework for circular economy strategy selection, underscores the imperative of incorporating diverse electronic products in recycling mandates. This necessitates the adoption of specialized technologies and policy reforms to mitigate the environmental and economic challenges posed by contemporary e-waste streams.

Financing Mechanisms

Financing approaches for electronics recycling programs in the United States generally fall into three broad categories: (1) point-of-sale consumer fees remitted to a public fund, exemplified by California's CEW fee structure and its periodic fee adjustments; (2) producer-funded systems, in which obligated manufacturers finance collection and recycling either directly or through Producer Responsibility Organizations (PROs), as seen in Washington's E-Cycle program and similar models nationwide; and (3) hybrid or municipal cost-share arrangements employed in some jurisdictions. The choice of financing model has significant implications for price signaling, administrative complexity, and the degree of producer influence over operational design. According to the National Center for Electronics Recycling (NCER), these structural decisions shape not only economic efficiency but also the adaptability of recycling systems to evolving product designs and material compositions (NCER, 2016).

Collection Targets and Performance Metrics

Annual reports by eCYCLE indicate that states employ varied metrics to evaluate the performance of electronics recycling programs, including absolute weight collected (e.g., pounds or tonnage), per-capita collection rates, diversion percentages, and device-specific recycling targets. Some programs, such as Washington's E-Cycle and local equivalents like the District of Columbia's eCYCLE, establish multi-year diversion milestones, while others rely on annual reporting of quantities collected and facility certification to demonstrate compliance. Although total pounds collected remains the most reported output metric, fewer jurisdictions publish standardized per-capita or material-recovery quality indicators, complicating efforts to compare program effectiveness across states (Washington State Department of Ecology, 2023). Linnell and Nash (2016) emphasize the need for streamlined performance metrics to enable meaningful cross-jurisdictional comparisons and to support policy evaluation and refinement.

Enforcement and Compliance Structures

California Department of Resources Recycling and Recovery highlights that enforcement mechanisms in state electronics recycling programs typically integrate producer registration and reporting requirements, plan approval or registration by a designated state agency, and oversight of certified collectors and processors. For example, California administers its CEW fee collection and participant eligibility through CalRecycle, supported by the California Department of Tax and Fee Administration. Washington maintains producer registries and performance reporting via the Department of Ecology, while New York enforces manufacturer registration and outreach obligations through the NYSDEC. In jurisdictions that empower Producer Responsibility Organizations (PROs), compliance oversight often shifts toward plan-level audits and reporting rather than direct producer management. As Quinto et al. (2025) observe, variations in staffing

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capacity, audit infrastructure, and statutory penalty frameworks contribute to uneven enforcement intensity across states, influencing program effectiveness and stakeholder accountability.

IV. COMPARATIVE ANALYSIS OF STATE-LEVEL OUTCOMES

Comparative evaluations and program-level analyses indicate that state-level EPR schemes for electronic waste consistently outperform unconstrained municipal systems in terms of documented collection and recovery rates, although performance remains uneven across jurisdictions and product categories (Parvez et al., 2021; Lifset et al., 2023). Syntheses of global and U.S. data reveal that overall documented e-waste recycling remains low relative to total generation, with global recovery rates estimated at approximately 22% in 2022 (Baldé et al., 2024). Heavier and bulkier devices tend to achieve higher capture and material recovery rates than smaller, battery-embedded electronics, reflecting differences in accessibility, economic value, and processing feasibility (Baldé et al., 2024).

State program data, such as those from California's Covered Electronic Waste (CEW) program and Washington's E-Cycle initiative, demonstrate substantial tonnage diversion under mature EPR frameworks. For example, Washington's E-Cycle program recycled over 163 million pounds of electronics in its first four years, averaging over 40 million pounds annually, with a statewide network of more than 320 collection sites. In California, the CEW program has been supported by a $1.3 billion payment system since 2005, enabling the diversion of significant volumes of hazardous e-waste and fostering a robust in-state processing infrastructure (Shah, 2022; CalRecycle, 2016; Washington State Department of Ecology, 2017). This notwithstanding, Rawat et al., (2024) argues that the recovery of hazardous constituents, such as lead, mercury, and brominated flame retardants is highly contingent on the comprehensiveness of collection systems and the rigor of downstream processor standards. Thus, increased collection volumes alone do not guarantee improved hazardous-material management without robust verification protocols and processor oversight. Figure 1 illustrates these long-term collection trends, highlighting California's early peak and gradual decline as CRT devices phased out, contrasted with Washington's steady performance under a producer-funded model, underscoring how program design influences sustainability.

Figure 1: ***Collection trends for California CEW and Washington E-Cycle programs, 2005-2023***.
Note. Data compiled from the California Department of Resources Recycling and Recovery (CalRecycle, 2023) and Washington State Department of Ecology (2023).

Economic Efficiency

The economic outcomes of electronic EPR programs are closely tied to financing architecture and scale. Producer-funded systems in Washington achieved estimated savings of $150 per ton compared to landfilling (Parvez et al., 2021). Producer-funded models, particularly collective Producer Responsibility Organizations (PROs) can realize economies of scale and streamline logistics for compliance multi-brand compliance (Lifset et al., 2023; Parvez et al., 2021). In contrast, point-of-sale fee systems, such as California's CEW model, offer transparent cost allocation to consumers but may introduce administrative burdens at the retail level and weaken incentives for eco-design modulation (Parvez et al., 2021).

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Ghulam & Abushammala (2023) emphasize that while delegating operational control to producers can enhance efficiency, such schemes must incorporate fee modulation, standardized reporting, and robust oversight to preserve incentives for product design innovation and prevent regressive cost pass-throughs that disproportionately affect low-income households. Empirical evaluations further suggest that administrative feasibility improves with centralized plan approval and standardized reporting templates, although initial implementation and audit costs remain significant, influencing net economic efficiency (Baldé et al., 2024).

Stakeholder Engagement

Comparative analyses of EPR programs in the United States reveal two interrelated findings: producer compliance is strongly influenced by the clarity of statutory obligations and the accessibility of plan-approval pathways (Parvez et al., 2021), while consumer participation is contingent on convenience, public awareness, and the availability of free or low-cost collection options (Forti et al., 2020; Ghulam & Abushammala, 2023). Consumer participation rates in states with free collection exceed 70%, compared to under 40% in fee-based systems (Forti et al., 2020). For example, Washington and New York, both offering free collection under producer-funded programs report participation rates above 70%, while California's fee-based CEW program shows rates closer to 35-40% (Washington State Department of Ecology, 2025; NYSDEC, 2024; CalRecycle, 2025). Jurisdictions such as New York and Washington, which mandate manufacturer registration, annual reporting, and approved collection networks, tend to exhibit higher administrative compliance rates. (NYSDEC, 2024; Washington State Department of Ecology, 2025). Concurrently, user surveys and empirical studies consistently identify the proximity of drop-off locations and retailer take-back programs as primary determinants of consumer engagement (Forti et al., 2020; Ghulam & Abushammala, 2023). EPR frameworks that integrate outreach initiatives and universal access targets are more likely to achieve substantial increases in household participation compared to baseline conditions (Forti et al. 2020). Nonetheless, heterogeneity in producer obligations and outreach funding across states contributes to uneven participation outcomes, underscoring the need for aligned policy instruments and implementation standards.

Challenges and Limitations

Policy fragmentation is a common theme in literature on electronics EPR. Significant variation in product scope, funding framework, measures of performance and reporting formats among U.S. states generate considerable compliance burden for national producers and limit the ability to compare across jurisdictions. Enforcement capacity shortfalls manifested in uneven audit intensity, variable penalty regimes, and limited agency resources undermine program accountability and effectiveness (Ghulam & Abushammala, 2023). Moreover, inconsistencies in data definitions (e.g., tonnage categories), reporting intervals, and verification protocols obstruct rigorous cost-benefit analysis and comparative evaluation (Ghulam & Abushammala, 2023). These limitations have prompted calls for interoperable reporting standards, minimum enforcement baselines, and coordinated multi-state or PRO-led arrangements to reduce administrative duplication while preserving regulatory flexibility and innovation (Baldé et al., 2024).

V. BARRIERS TO NATIONAL HARMONIZATION

To begin with, regulatory fragmentation is the most-cited structural barrier to national harmonization. States have led electronics EPR adoption, producing a mosaic of statutes with varied scopes, obligations, and administrative models that create divergent product definitions, reporting formats, fee arrangements, and performance expectations, conditions that complicate cross-jurisdictional comparability and raise administrative burdens for multi-state compliance (OECD, 2024; Baldé et al., 2024). For instance, California excludes printers, while New York includes them as covered devices. Industry dynamics and political economy further constrain national reform. Producer resistance and organized lobbying over compliance costs and competitive impacts shape policy debate and encourage state-level tailoring, while complex supply chains (multiple importers, brand fragmentation, and global product lines) make mapping obligations to responsible actors difficult and increase industry pushback against uniform national rules (Parvez et al., 2021; Ghulam & Abushammala, 2023). Moreover, technical and administrative constraints, thus, data-sharing gaps, inconsistent reporting intervals and verification protocols, and uneven recycling infrastructure, including rural coverage gaps and variable downstream capacity, obstruct aggregation and robust cost-benefit comparisons and would require substantial interoperable data standards and infrastructure investment before a national regime could be equitably imposed (Baldé et al., 2024; Ghulam & Abushammala, 2023). These challenges are compounded by fragmented data architectures, misclassification of used electronics, and weak customs scrutiny that permit harmful exports (Norgbey & Cudjoe-Mensah, 2025). Additionally, legal questions about federal preemption, and the political challenge of coordinating agencies and stakeholders with differing capacities and priorities, mean pragmatic harmonization strategies will likely need phased minimum federal baselines, interoperable reporting standards, and stakeholder engagement to mitigate resistance while preserving state flexibility (OECD, 2024). This tension is not without precedent: *in National Electrical Manufacturers Association (NEMA) v. Sorrell (2004),* the Second Circuit upheld Vermont's producer-responsibility labeling requirements against industry claims of federal preemption, exemplifying the judiciary's historical approach to reconciling federal authority with state autonomy in the realm of environmental product regulation.

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VI. RECOMMENDATIONS

High-performing state-level EPR programs for electronics consistently demonstrate that success is rooted in a combination of:

- **Statutory clarity** - clearly delineating producer obligations, with tiered classifications that enhance regulatory precision and equity.
- **Stable financing** - using models anchored in Producer Responsibility Organizations (PROs) or point-of-sale fee systems to provide predictable funding and administrative resilience.
- **Centralized oversight** - implementing systems for registration and plan approval that streamline compliance and improve enforcement capacity, as evidenced by programs in California and Washington.
- **Inclusive outreach** - establishing accessibility standards and targeted engagement, particularly in rural and underserved communities, to foster environmental justice and broad stakeholder participation.

To scale these successes nationally, standardization must prioritize interoperability over uniformity. Additionally, aligning definitional standards, adopting machine-readable reporting templates, and supporting shared registries or a federally backed clearinghouse can reduce administrative duplication and facilitate multi-state compliance. Federal engagement should also focus on enabling convergence through grants, technical assistance, and phased performance baselines, rather than imposing rigid mandates. The U.S. EPA's Solid Waste Infrastructure for Recycling (SWIFR) grant program could serve as a model for funding harmonization efforts. Finally, the review concludes that EPR systems require inclusive governance with representation from producers, regulators, and civil society, and are institutionalized through public reporting, independent verification, and audits to ensure trust and accountability.

VII. CONCLUSION

This review has synthesized empirical evidence and comparative policy analysis to evaluate the effectiveness of state-level EPR programs for electronics in the United States. It finds that program success is contingent upon statutory clarity, stable financing, centralized oversight, and inclusive outreach. These elements collectively enhance material recovery, stakeholder compliance, and environmental equity. The analysis further demonstrates that while state-level innovation has yielded valuable experimentation, regulatory fragmentation imposes significant compliance burdens and undermines national coherence. In response, this review proposes a harmonization framework that preserves state autonomy while enabling interoperability through standardized reporting, phased federal baselines, and coordinated governance. Our review contributes to the discourse on sustainable electronics policy and offers a strategic blueprint for scaling EPR nationally. Future research should explore the operational feasibility of shared registries, the equity implications of fee structures, and the role of design incentives in circular economy transitions. Ultimately, a standardized yet flexible EPR architecture is essential for aligning U.S. electronics waste policy with broader sustainability and accountability goals. Without harmonization, the U.S. risks escalating compliance costs, widening recycling gaps, and missing circular economy targets.

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