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CIRCULAR ECONOMY POLICY HANDBOOK

GLOBAL GOOD PRACTICES AND POLICY RECOMMENDATIONS FOR TWIN TRANSITION

REUSE



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26.10.2026

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26.10.2026

Editors' Note

The transition towards a sustainable economy has increasingly become a question of how societies organize production, allocate resources, develop technological capabilities, and govern economic interdependence. Environmental sustainability and digital transformation, once approached largely as distinct policy domains, are now deeply interconnected. Their convergence is reshaping industrial structures, regulatory frameworks, international trade relationships, and the distribution of economic opportunities. Yet the relationship between these transformations is neither automatic nor necessarily complementary. Digital technologies may facilitate more efficient material use, while circular production systems may create new opportunities for innovation and industrial competitiveness. Whether these developments contribute to broader sustainability objectives, however, depends fundamentally on the institutions, policies, and economic conditions through which they are implemented.

This policy handbook, prepared within the framework of the ***Jean Monnet Module- REUSE*** brings together interdisciplinary contributions examining the policy dimensions of circularity and digitalization across different national, institutional, and industrial contexts. Rather than treating the twin transition as a predetermined pathway towards sustainability, the contributions invite a more critical examination of the economic structures, regulatory choices, and governance arrangements that shape its implementation.

At the center of this discussion lies a fundamental distinction between adopting circular practices and establishing a circular economy. Recycling, resource recovery, repair, remanufacturing, and material efficiency represent important components of the transition, but their broader economic significance depends on the systems in which they operate. Meaningful transformation requires coordination between technological capabilities, market incentives, regulatory institutions, productive infrastructure, and social participation.

The contributions to this handbook approach the twin transition from complementary disciplinary, geographical, and sectoral perspectives, reflecting the diversity of economic and institutional conditions under which circular economy policies are developed and implemented. Although sustainability objectives may be broadly shared, the pathways towards achieving them differ according to productive structures, technological capabilities, regulatory frameworks, and access to resources. These differences underscore the limitations of uniform policy approaches and highlight the importance of context-sensitive governance. Across the contributions, a common concern emerges: translating environmental ambitions into coherent policy frameworks that reconcile

economic viability, industrial competitiveness, institutional effectiveness, and social inclusion.

Within this broader perspective, digitalization, regulatory innovation, and economic incentives are examined as interconnected dimensions of the transition rather than independent policy objectives. Their potential contributions depend on effective coordination among public institutions, businesses, and other stakeholders, as well as the capacity to address unequal adjustment costs and technological disparities. The handbook consequently places particular emphasis on the relationship between policy design and implementation, recognizing that sustainable transformation requires more than technological advancement or regulatory commitments. It also depends on the development of productive capabilities, accessible financing, institutional cooperation, and the equitable distribution of opportunities and responsibilities. Taken together, these perspectives position the twin transition as a multidimensional process of economic and institutional change, with implications extending well beyond environmental performance.

Taken together, these perspectives suggest that the twin transition should be understood as an interconnected process of institutional and economic restructuring. Its implications extend beyond waste reduction or technological modernization to questions of productivity, competitiveness, industrial development, and resilience. Circularity may reduce selected forms of resource dependence while creating new requirements for specialized technologies and processing capabilities. Digitalization may improve coordination while increasing the importance of data governance and technical expertise. Green industrial policies may support the development of domestic capabilities while also altering international trade relationships. These interactions underline the need to evaluate sustainability policies through their combined environmental, economic, and social consequences rather than through isolated performance indicators.

Within this broader framework, the European Union provides an important reference point for examining the governance of the twin transition. Its evolving policy approach demonstrates the increasing interaction between environmental regulation, industrial strategy, digital governance, and international economic relations. However, the relevance of European policy experience extends beyond the replication of particular regulatory instruments. Comparative perspectives are essential for identifying which institutional principles may be transferable, which implementation conditions remain context-specific, and how international cooperation can accommodate different levels of economic and technological development. The contributions in this volume reflect this wider understanding by examining European policy developments alongside experiences from Asia, Africa, and Latin America.

The Jean Monnet Module- REUSE provides an academic setting for these discussions by connecting European Union policy studies with interdisciplinary research on circular economy governance and digital transformation. The present publication reflects the importance of bringing different scholarly traditions and geographical perspectives into a shared policy conversation. Environmental regulation cannot be examined independently of economic incentives; technological innovation cannot be separated from institutional capacity; and industrial resilience cannot be understood without considering international production networks and the distribution of economic value.

As editors, we regard the diversity of approaches represented in this policy handbook as an essential contribution to that conversation. The chapters do not propose a single model of circular economic development, nor do they suggest that identical policy instruments will generate equivalent outcomes across countries and industries. Instead, they identify distinct regulatory challenges, institutional arrangements, sectoral practices, and policy possibilities that invite further comparative investigation. Their collective significance lies in expanding the discussion from the desirability of the twin transition towards the conditions under which it can be governed effectively.

We extend our appreciation to the contributing authors for sharing their research, analytical perspectives, and policy insights. We hope that it will serve as a useful resource for researchers, educators, policymakers, and practitioners concerned with the evolving relationship between sustainability, technological transformation, and industrial development.

Ultimately, governing the twin transition requires more than promoting circular practices or accelerating digital adoption. It requires institutions capable of coordinating economic and environmental priorities, policies attentive to unequal adjustment capacities, and cooperation that preserves opportunities for productive development across different economies. The central question is not simply how rapidly circularity and digitalization can advance, but how their interaction can contribute to economies that are more resource-efficient, resilient, inclusive, and sustainable.

The Editors

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CIRCULAR AND URBAN MINING IN CHILE: POLICY PATHWAYS FOR THE SAFE VALORIZATION OF TAILINGS, SLAG AND TECHNOLOGICAL WASTE

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Chile has a strategic opportunity to connect its mining vocation with the circular economy. The country produces and manages large flows of mine tailings, copper slags, used tyres, lubricating oils, batteries, electrical and electronic equipment, cables and other industrial residues. At the same time, the energy transition is increasing demand for copper, lithium and other critical materials. These two realities create a policy question of national relevance: under what conditions can wastes and residues become safe, traceable and economically credible secondary resources rather than new environmental liabilities?

The challenge is not merely technological. Circularity requires a coordinated framework that links waste regulation, mine-closure obligations, environmental assessment, material quality, market demand, territorial governance and long-term responsibility. Chile already has important elements of this framework. Law No. 20,920 establishes extended producer responsibility and promotes recycling; mining residues and tailings are also governed by environmental legislation, specific tailings regulation and mine-closure rules. The 2025-2026 Tailings Agenda further encourages improved inventories, remediation and reprocessing. However, these instruments do not yet operate as a fully integrated policy architecture for secondary mining and material valorization (Biblioteca del Congreso Nacional de Chile, 1994, 2007, 2011, 2016; Ministry of Mining, 2025).

A central policy risk is to confuse reuse with circularity. Moving a residue from a controlled facility into a product or another territory is

not necessarily a circular solution. A circular pathway should demonstrate a net reduction in environmental liability, control of contaminant release, acceptable resource consumption, technical performance, traceability and a verifiable market. This principle is especially important for tailings, slag and construction applications, where mechanical suitability alone is insufficient.

Chilean experience and emerging good practices

Chile possesses several advantages for developing circular and urban mining. Its mining regions concentrate laboratories, metallurgical suppliers, hydrometallurgical expertise and solvent-extraction/electrowinning infrastructure. These capabilities can be adapted to secondary feedstocks, provided that their composition and variability are adequately characterized. Studies of Chilean tailings have identified occurrences of vanadium, rare earth elements and other potentially valuable components, but they also show that occurrence is not equivalent to an economically recoverable reserve. Mineralogy, grade, tonnage, recovery, scale, co-products and capital expenditure must be assessed together (Araya et al., 2020, 2021; Villa-Gómez et al., 2022).

Copper slag offers another relevant example. Recovery of entrained copper through milling and flotation can both generate value and reduce the metal content of the residual material. Evidence from the Hernán Videla Lira smelter illustrates the practical relevance of this approach, while recent reviews emphasize that leaching routes must be adapted to mineralogy, impurities, acid consumption and water balance rather than applied as universal solutions (Arancibia-Zúñiga et al., 2026; Valderrama et al., 2024).

Urban mining can complement these mineral residues. Mining operations and their supply chains continuously replace motors, sensors, drives, computers, telecommunications equipment, batteries and vehicles. These streams contain copper, aluminium, iron, precious metals, cobalt, nickel, lithium, manganese and other materials of interest. A good-practice hierarchy is therefore to extend product life first, repair and remanufacture where possible, then dismantle and sort selectively before metallurgical recovery. This increases feed quality and avoids spending energy and reagents on components that could have remained in use (Mohamed et al., 2025; Roskladka et al., 2025).

The most promising institutional model is regional industrial symbiosis: mining companies, technology suppliers, authorized waste

managers, recyclers, laboratories, municipalities and material users linked through traceable flows. Such networks can create sufficient scale for shared characterization facilities and pilot plants, while reducing logistical costs. They can also help integrate smaller firms and formal recyclers into higher-value chains, provided that occupational and environmental safeguards are explicit.

Policy recommendations

1. Establish a national secondary-resource characterization standard. Chile should define minimum datasets for tailings, slags, WEEE and batteries before they are promoted as secondary resources. These datasets should include tonnage, sampling quality, mineralogy or material composition, particle-size distribution where relevant, hazardous constituents, recoverability, uncertainty and ownership. Standardized data would reduce investment risk and improve comparability between projects.

2. Create a clear end-of-waste and secondary-material pathway. Regulation should specify when a processed residue can cease to be managed as waste and enter the market as a secondary raw material. The decision should depend on demonstrated technical performance, leaching and durability, traceability, intended use, quality control and residual environmental responsibility. Clear rules would protect users and communities while reducing regulatory uncertainty for legitimate projects.

3. Apply a circularity hierarchy to mining procurement and waste management. Policy and corporate practice should prioritize prevention, life extension, repair and remanufacturing before recycling; selective metal recovery should precede lower-value material use where technically and environmentally justified. Only stabilized and demonstrably safe matrices should enter construction or other long-lived applications. Secure disposal remains necessary when circular routes do not reduce overall risk.

4. Develop shared regional pilot and demonstration infrastructure. Public-private facilities in mining regions could test comminution, flotation, leaching, separation, purification and stabilization at pre-commercial scale. Shared facilities would be particularly valuable for heterogeneous residues and for small and medium-sized firms that cannot justify dedicated pilot plants. Antofagasta, Atacama and Coquimbo are natural candidates for mining-

residue pilots, while the Metropolitan Region can strengthen urban-mining and WEEE capabilities.

5. Require life-cycle and liability-reduction evidence in public support schemes. Grants, tax incentives or preferential procurement for circular projects should be conditional on measurable reductions in liability and environmental burden. Evaluation should include water and reagent use, energy demand, effluents, transport, greenhouse-gas implications, contaminant mobility, residual volumes and long-term stability. This would discourage projects that simply relocate risk.

6. Introduce material passports and batch traceability for secondary materials. Digital traceability can connect origin, characterization, treatment, quality testing, destination and responsible actors. For WEEE and batteries, it would support reverse logistics and producer-responsibility systems; for mining residues, it would improve confidence in secondary products and facilitate auditing. Digitalization should therefore be treated as an enabling component of circular policy rather than an independent objective.

7. Use public and large-company procurement to create reliable demand. Secondary materials often fail not because recovery is technically impossible, but because markets are uncertain. Procurement standards can create demand for certified recycled aggregates, recovered metals or remanufactured equipment when safety and performance requirements are met. Long-term offtake agreements can also improve the bankability of recovery projects.

8. Integrate territorial participation and long-term responsibility. Reprocessing projects can alter transport patterns, water use, dust, noise and perceptions of risk. Early engagement with communities and local authorities should therefore accompany technical assessment. Reprocessing must not extinguish pre-existing environmental duties automatically; responsibility for residual materials and future performance should remain explicit.

Transferability to other contexts

The Chilean case is transferable to other mining economies because the underlying policy problem is common: legacy residues may contain valuable materials, yet technical opportunity does not by itself justify reprocessing or reuse. Countries with large mining districts can

adopt the same decision sequence: characterize the residue; identify a technically mature recovery route; quantify environmental and economic performance; establish product-quality and end-of-waste criteria; secure a market; and define responsibility for residual liabilities.

The approach is also relevant beyond mining. Urban regions managing WEEE, batteries and construction waste face the same need for traceability, quality assurance and market creation. The transferable lesson is that circular economy policy works best when regulation, technology, digital information, market instruments and territorial governance are designed together. A project should be described as circular only when it produces demonstrable net benefits over the life cycle and does not shift environmental burdens to another place, population or future period.

Conclusion

Chile can turn part of its mining and urban waste burden into a strategic source of secondary materials, but the objective should not be maximum recycling at any cost. The appropriate objective is safe and verifiable value recovery combined with a measurable reduction of environmental liability. The country's metallurgical capabilities and emerging regulatory instruments provide a strong starting point, while the principal gaps concern standardized information, end-of-waste criteria, certification, traceability, market formation and coordination among institutions.

A pragmatic circular-mining policy should therefore combine a hierarchy of prevention and reuse, selective recovery of high-value materials, safe valorization of stabilized matrices, and controlled disposal for unavoidable residues. If these routes are supported by transparent data, shared pilot infrastructure, digital material passports, life-cycle evidence and clear responsibility, Chile can develop a model that is both nationally useful and transferable to other resource-intensive economies.

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IMPLEMENTATION OF AN EFFECTIVE TAX INCENTIVE STRATEGY IN DRIVING ADVOCACY TOWARDS A CIRCULAR ECONOMY

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INTRODUCTION

The circular economy is basically a model designed for sustainable production and consumption involving sharing, leasing, reusing, repairing, refurbishing and recycling existing materials (products) as much as practically possible[1]. By doing so, the life cycle of the products is extended. In all practice purpose it seeks to reduce waste to a lowest minimum. When a product reaches the end of its life, its materials are re-cycle within the economy of a nation[2]. By this method, the product can be used and reused again and again without creating new waste and thereby creating further value. The CE model[3] is far better than the traditional, linear economic models which is driven by a wasteful "take-make-consume-throw away" habit. Of course, to implement this, there is a need to ensure that there exist a large volume of obtainable materials and energy to sustain the CE process.

ROLE OF TAX INCENTIVE

The need to implement a circular economy is an on-going process in many developing countries, including developed countries. One main reason is to protect the environment in line with UNSDG

[1] European Parliament. (2023, May 24). Circular economy: Definition, importance and benefits. https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits

[2] Stahel, W. R. (2016). The circular economy. Nature, 531, 435–438. https://doi.org/10.1038/531435a

[3] Velenturf, A. P., & Purnell, P. (2021). Principles for a sustainable circular economy. Sustainable Production and Consumption, 27, 1437–1457. https://doi.org/10.1016/j.spc.2021.02.018

17[4]. By reusing and recycling products this minimize the need to use more natural resources, and thus reduce environmental destruction and preserve biological diversity loss as much as possible. This will provide countries leverage towards another big goal in reducing global greenhouse gas emissions as guided by the Paris Agreement 2015[5] on climate change imperatives. The role of tax incentive[6] is pertinent as well within the CE framework. Tax is used frequently to motivate and encourage business and industry[7] to add value to the compliance exercises[8] in achieving climate change targets in many ways[9]. Many questions are raised on this aspect. How the circular economy fits with potential taxation incentive developments on business and industry[10].

GLOBAL STANDARD: EU CASE STUDY

Even in the European Union (EU) as a whole, waste is a big problem. Irt is reported that EU produces roughly 2.1 billion tonnes of waste every year. To drive advocacy towards adopting a sustainable development model known as the circular economy (CE). This requires an urgent need to implement critical measures[11] such as new CE-related legislation on waste management, and tax incentives is one of the driving advocacy instruments as the world moves to CE.

---

[4] United Nations. (2026). The 17 goals. https://sdgs.un.org/goals

[5] United Nations Framework Convention on Climate Change. (2026). *The Paris Agreement*. https://unfccc.int/process-and-meetings/the-paris-agreement

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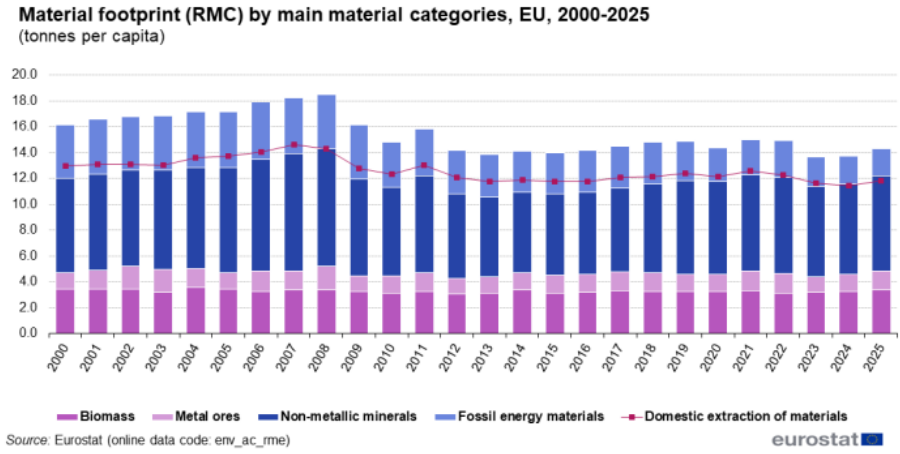
[9] Valencia, M., Bocken, N., Loaiza, C., & De Jaeger, S. (2023). The social contribution of the circular economy. Journal of Cleaner Production, 408, Article 137082. https://doi.org/10.1016/j.jclepro.2023.137082

[10] KPMG International. (2026). Taxation and the circular economy. https://kpmg.com/xx/en/our-insights/esg/taxation-and-the-circular-economy.html

[11] Milios, L. (2021). Towards a circular economy taxation framework: Expectations and challenges of implementation. Circular Economy and Sustainability, 1(2), 477–498. https://doi.org/10.1007/s43615-020-00002-z

Towards this goal, the Eu is actively working hard to reach a CE economy by year 2050 that will see new CE transformation in waste reduction and sustainable products.

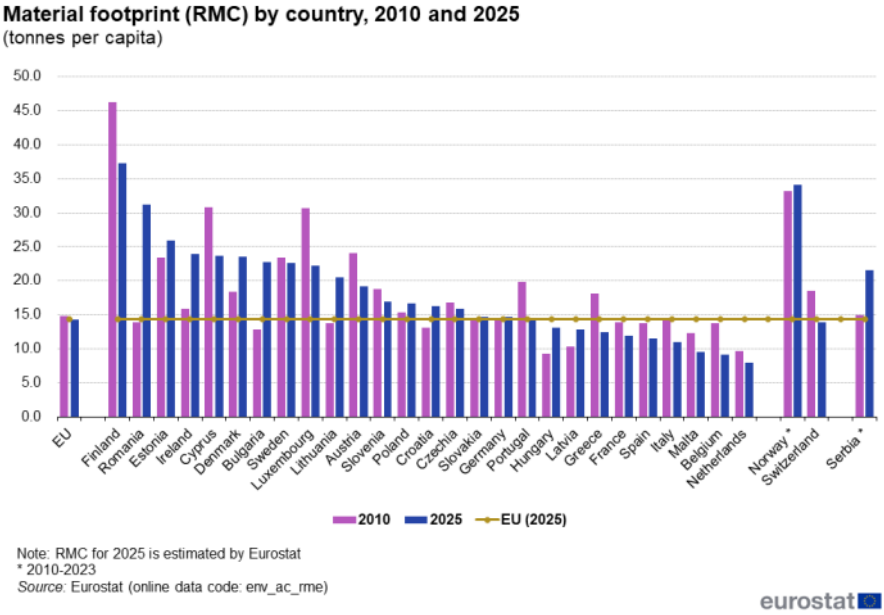
EU's material footprint by material is in need of serious transformation in line with CE expectations in many aspects. The material footprint of the EU known as raw material consumption (RMC) shows the total amount of extracted raw materials needed to produce the goods and services consumed by residents of the EU. The following figure shows how the EU material footprint developed from 2000 to 2025.



Eurostat. (2026, July 27). Material flow accounts statistics – material footprints. European Commission. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Material_flow_accounts_statistics_-_material_footprints

In terms of material, the material footprint of European countries is shown in the figure below shows the material footprints for European countries where in 2025, 10 EU countries remained below the EU value of 14.3 tonnes per capita. This is a good case study for observation as the world moves towards better environmental compliance and advocacy for a true CE economy.

Material footprint (RMC) by country, 2010 and 2025



Eurostat. (2026, July 27). Material flow accounts statistics – material footprints. European Commission. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Material_flow_accounts_statistics_-_material_footprints

MALAYSIA CASE STUDY

There are several positive motivations for business and industry to join into the CE advocacy[12]. In Malaysia, and in many developing countries as well there is currently no mandatory requirement for all industries and businesses to implement CE. The approach taken is to implement CE advocacy in certain industries to manage the CE compliance effectively. The Malaysian government is shifting its policy from "voluntary participation" to industry specific mandatory CE regulatory enforcement for examples in the

[12] Ting, L. S., Zailani, S., Sidek, N. Z. M., & Shaharudin, M. R. (2024). Motivators and barriers of circular economy business model adoption and its impact on sustainable production in Malaysia. Environment, Development and Sustainability, 26(7), 17551-17578. https://www.researchgate.net/publication/370980362_Motivators_and_barriers_of_circular_economy_business_model_adoption_and_its_impact_on_sustainable_production_in_Malaysia

manufacturing, packaging, and waste management. At the same time, this is back by tax incentives if the business adopted sustainable practices to reduce carbon footprints. The implementation landscape is slowly seeing changes.

EPR POLICY AS SUPPORTING CE ECONOMY

In Malaysia, this is seen in the policy implementation of the Mandatory Extended Producer Responsibility (EPR) by 2029 driven by the Ministry of Investment, Trade and Industry (MITI). MITI has set up a Circular Economy Policy Framework for the Manufacturing Sector[13] (CE Framework) to guide industrial implementation. According to this CE Framework, an Extended Producer Responsibility (EPR) system will become compulsory by 2029. Targets by year 2030 have been designed based on four clear themes.

[13] Aoki, K. (2024, November 20). Malaysia publishes circular economy policy framework for manufacturing sector. Enviliance ASIA. https://enviliance.com/regions/southeast-asia/my/report_12767

Theme	Expectation	Proposed Targets
Circular Input	Robust local CE industry with a consistent supply of circular materials Closed production loops reinforced by strong supply chain linkages, including with local CE industry	4 times the circular material use rate vs. year 2019 (0.3% in 2019)
Efficient Process	High-quality products produced with resource-efficient design, production & distribution Technological excellence and productivity at the core of manufacturing companies	30% increase of USD generated per ton of raw material vs. year 2019 (USD 539/ton in 2019)
Sustainable Output	Industry-leading reduction of manufacturing waste at source through Best Environmental Practices (BEP) Innovative redirection of by-products for use in other manufacturing applications	Industry Waste Intensity reduction by 20% vs. year 2019
Socioeconomic Impact	Hub for innovation and entrepreneurship in CE Enhance people's quality of life through good jobs and less pollution Achieving a just transition towards CE	Gross Value added from circular economy 3 times vs. year 2019 (RM6.3 billion in 2019)

Adapted from Ministry of Investment, Trade and Industry. (2024). Circular economy policy framework for the manufacturing sector in Malaysia. https://www.nimp2030.gov.my/nimp2030/resources/NIMP%20Banner/CIRCULAR_ECONOMY_POLICY_FRAMEWORK.pdf

The Implementation Timeline is set out as follows.

2024 4th quarter	Drive transition to mandatory EPR adoption amongst manufacturers Develop guidelines for manufacturers on classification of non-hazardous industrial output / waste Promote circular business models
2025	Create critical material trade list Launch of CE certifications Support export of goods with CE requirements & attract high-value CE investments Establish robust national CE metrics and tracking mechanism
2026	Publication of CE monitoring system and announce live dashboard Upskilling Programs
2027	Legislation of minimum circular content requirements especially for packaging, electric & electronic equipment, consumer goods Mandatory sorting of non-hazardous waste Business-to-business waste marketplace Publication of CE taxonomy (e.g. Standardization of definitions such as “Recycle”, “Reuse”)
2028	Publication of EPR recommendation paper
2029	Mandatory minimum circular content requirement in effect Legislation of mandatory EPR Launch of mandatory labelling for CE products

Adapted from Ministry of Investment, Trade and Industry. (2024). Circular economy policy framework for the manufacturing sector in Malaysia. https://www.nimp2030.gov.my/nimp2030/resources/NIMP%20Banner/CIRCULAR_ECONOMY_POLICY_FRAMEWORK.pdf

A brief analysis can be made here. Base on the above figure, it is anticipated that by 2029, the mandatory minimum circular content requirement will be put into enforcement, and there will be a new EPR to support CE economy. This includes a need for a new law on mandatory EPR

The CE Analysis

Manufacturers will be responsible for the entire lifecycle of their products from the collection, recycling, or disposal of their post-consumer packaging and waste. Further on material obligations aspect, manufacturers will be obligated to integrate circular materials (recycled, remanufactured, or reused inputs) into their production lines.

Enforcement Measure

The CE advocacy is further strengthened by enforcement by way of strict penalty. This is of course incorporated form the UNFCCC reality to transform the market and industry towards CE ready model[14]. Malaysia is implementing new CE-related policy[15], the "Polluters-Pay" principles by heavy fines and carbon taxes for environmental pollution and destruction. Another important note is that the Global Supply Chains is seeing compliance towards CE model[16] as well. Major international markets[17] like the EU and even US are seeing new levels of compliance with ESG and CE criteria. As Malaysia is highly geared towards manufacturing exports, local suppliers have no choice but to set up implementation that fits with the CE requirement or risk losing global

[14] Milios, L. (2021). Towards a circular economy taxation framework: Expectations and challenges of implementation. Circular Economy and Sustainability, 1, 477–498. https://doi.org/10.1007/s43615-020-00002-z

[15] Li, K., Salleh, H. B., Wang, R., & Yang, Y. (2025). How do different policy instruments influence circular economy implementation in the construction sector? Building Research & Information, 53(3), 359–374. https://doi.org/10.1080/09613218.2024.2426466

[16] Milios, L. (2021). Towards a circular economy taxation framework: Expectations and challenges of implementation. Circular Economy and Sustainability, 1, 477–498. https://doi.org/10.1007/s43615-020-00002-z

[17] Guglyuvatyy, E., & Stoianoff, N. (2026). Taxing for sustainability: Australia and Malaysia's fiscal path to a circular economy. Circular Economy and Sustainability, 6, Article 198. https://doi.org/10.1007/s43615-026-00814-5

buyers. A summary of the transition is presented in the table below for better understanding.

Aspect	Current Status (2026)	Near-Term Status (By 2029/2030)
For Consumers	Highly encouraged; partial localized waste-sorting rules.	Increasing pressure via local council sorting mandates.
For Manufacturers	Transitioning; voluntary EPR groups active (e.g., MAREA).	Strictly Compulsory under MITI framework & EPR laws.
For Listed Corporates	Expected under rigid ESG and compliance reporting.	Linked to mandatory carbon taxes and environmental liability.

STRATEGISING TAX INCENTIVE POLICY

Hence there is a real business need to adopt an effective tax incentive strategy to maximise whatever opportunities are given by the government towards fitting with the CE requirement. In implementing advocacy for CE economy[18], besides EPR policy above, Malaysia is providing several strong tax incentives to promote CE economy. The 1st policy incentive is the Green Investment Tax Allowance (GITA)[19]. It provides for a 100% capital allowance on qualifying assets for approved green technology investments. This covers waste recycling and composting infrastructures. The other tax incentive is the Green Income Tax Exemption (GITE)[20]. It provides for a 70% income tax exemption

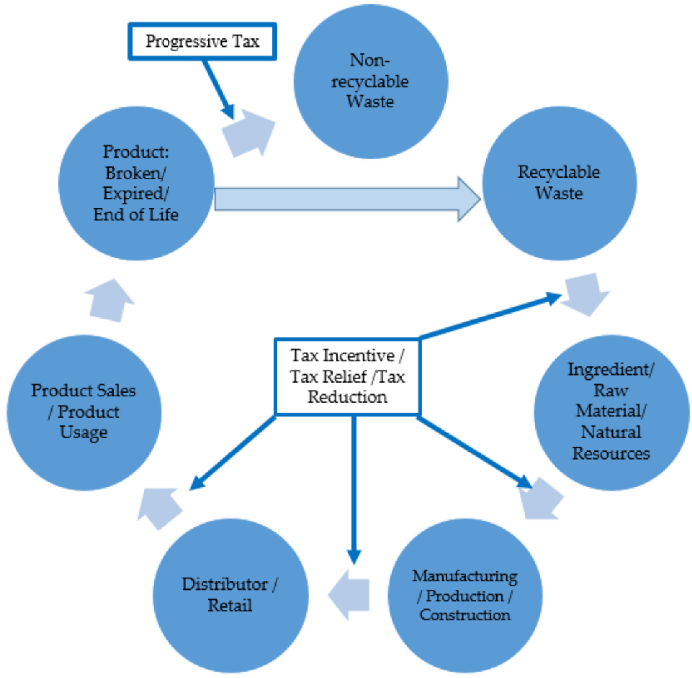
[18] Malaysian Investment Development Authority. (2026). Turning waste into wealth: Malaysia's circular economy in action. https://www.mida.gov.my/turning-waste-into-wealth-malaysias-circular-economy-in-action/

[19] On GITA, see Malaysian Investment Development Authority. (2026). Green technology. https://www.mida.gov.my/industries/services/green-technology/

[20] On GITE, see Malaysian Investment Development Authority. (2026). Green technology.

for up to 10 years for green service providers for example qualified waste management and recycling operations subject to specific conditions under GITE conditions. Other than GITA and GITE which are both good tax incentives moving forward, there is also the Green Technology Financing Scheme (GTFS)[21]. It provides government guarantees and rate subsidies and Low Carbon Transition Facility for business promotion. All these GITA, GITE, GTFS in many ways support the CE economy leading to better compliance with UNSDG 17 as a whole.

Tax incentives as a national policy is possible to drive CE economy. A study has show using Indonesia a s case study that it is a god and effective driver in supporting CE economy especially in terms of progressive tax as a working example.



Lestari, E. R. (2023). Tax policy reconstruction toward implementation of circular economy in Indonesia. Proceedings, 83(1), Article 68. https://doi.org/10.3390/proceedings2022083068

https://www.mida.gov.my/industries/services/green-technology/

[21] Malaysian Green Technology and Climate Change Corporation. (n.d.). Green Technology Financing Scheme. https://www.mgtc.gov.my/our-services/green-technology-financing-scheme/

In support of CE economy using tax incentives policy and strategy, the tables below represent a good observation for policy implementation by business and industries covering several key themes from end of life, to use and production levels. This table is useful in designing an effective tax incentive policy and strategy in parallel with the imperatives of CE economy.

Tax and the Circular Economy

Category	Description
Tax & the Circular Economy	Businesses should be aware of the different levers that governments have used to support and accelerate the transition to a circular economy. Relevant instruments include taxes, tariffs, tax reliefs and subsidies.
Tax at the end-of-life stage	Taxes on raw materials only address external costs arising from extraction or production processes, but not those associated with waste disposal. Both upstream and downstream impacts may need to be considered. Taxes have therefore been introduced at the end-of-life stage of products to address these impacts.
Tax at the use stage	Globally, interoperability is a significant problem in healthcare. At the 2023 Oracle Health Conference, Oracle announced plans to remain open and connected, including for health systems or providers that had invested in other electronic health record (EHR) systems. This raises questions about the guidance provided to clients developing strategies for working with Oracle in the future, particularly when they already use a different EHR system.
Tax at the production stage	From an implementation perspective, several issues should be considered: (1) Increasing costs, particularly in the short term, as alternative raw materials or technologies may not be available; (2) the impact of cross-material substitution effects;

Category	Description
	and (3) potential impacts on trade and industries from a broader perspective.

KPMG International. (2024, June). Taxation and the circular economy: What it means for business. https://kpmg.com/xx/en/our-insights/esg/taxation-and-the-circular-economy.html

Conclusion

The role of tax incentive in driving support for CE economy is crucial and gaining momentum as governments around the world utilise tax role to supplement implementation with the anticipation of the CE economy. The CE standards set by EU and the cross-border trade implication on Malaysia and Indonesia including the majority of developing countries serves as notable case study in designing an effective tax incentive strategy for business, stakeholders and local governments. The findings provide for good comparative analysis and insights on the positive tax incentive argument that in many ways and levels, support the CE model, and drive implementation towards better compliance with sustainable requirements within UNSDG 17 framework for a better CE economy.

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Guglyuvatyy, E., & Stoianoff, N. (2026). Taxing for sustainability: Australia and Malaysia's fiscal path to a circular economy. Circular Economy and Sustainability, 6, Article 198. https://doi.org/10.1007/s43615-026-00814-5

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DIGITALIZING EXTENDED PRODUCER RESPONSIBILITY: A POLYCENTRIC GOVERNANCE APPROACH TO TRANSNATIONAL E-WASTE FLOWS

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Abstract

Electronic waste (e-waste) represents the fastest-growing municipal waste stream globally, posing profound legal, environmental, and public health challenges. While domestic Extended Producer Responsibility (EPR) frameworks have gained traction in developed economies, their enforcement falters across borders, resulting in massive illegal transfers of hazardous used electrical and electronic equipment (UEEE) to developing nations. This paper conceptualizes a digitally integrated, polycentric approach to transnational e-waste regulation, balancing environmental protection and technological innovation. It introduces a comprehensive Geographical Transferability Matrix designed to navigate divergent socio-legal, technical, and regulatory environments in West Africa, South Asia, and Latin America. By evaluating port ledger harmonization through QR codes in West African marine junctions, national digital identity tokenization within the segmented informal structures of South Asia, and geolocation reverse logistics frameworks in Latin American smart city networks, this study establishes scalable guidelines for global policy diffusion. The analysis underscores how digital architectures can institutionalize cross-border circular economies while respecting localized informal baseline economies. Ultimately, this polycentric framework provides a scalable model to advance the United Nations Sustainable Development Goals (SDGs), specifically targets within SDG 3 (Good Health), SDG 8 (Decent Work), SDG 11 (Sustainable Cities), and SDG 12 (Responsible Production).

***Keywords*:** Extended Producer Responsibility (EPR), E-Waste, Polycentric Governance, Digital Product Passports, Informal Economy, Smart Cities.

The contemporary surge in technological innovation has exponentially expanded consumer access to consumer electronics, while concurrently generating an unprecedented global crisis, electronic waste (e-waste). Formally defined as discarded electrical or electronic equipment (EEE), including all components, subassemblies, and consumables that are part of the product at the time of discarding, e-waste has emerged as the fastest-growing municipal solid waste stream globally (United Nations Institute for Training and Research [UNITAR], 2024). Under international environmental law, primarily the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (1989), a significant proportion of e-waste is categorized as hazardous due to toxic constituents such as mercury, lead, cadmium, brominated flame retardants, and polychlorinated biphenyls.

Despite multilateral environmental agreements (MEAs), enforcement deficits persist across jurisdictional boundaries. Developed market economies regularly exploit systemic gaps in legal classifications, routing hazardous e-waste to developing nations under the deceptive label of "Used Electrical and Electronic Equipment" (UEEE) destined for philanthropic reuse or refurbishing (United Nations Environment Programme [UNEP], 2015). When these transboundary flows arrive in developing regions, they frequently bypass formal management facilities, moving directly into under-regulated informal sectors (Nnorom & Osibanjo, 2008). Within these sectors, processing relies heavily on primitive methods such as open-air burning, acid bathing, and physical dismantling. These practices lead to devastating environmental contamination, bioaccumulation of heavy metals, and acute occupational illnesses among vulnerable demographics (World Health Organization [WHO], 2023).

To mitigate these challenges, modern environmental jurisprudence champions Extended Producer Responsibility (EPR). As an environmental policy approach, EPR mandates that a producer's financial and physical responsibility for a product is extended to the post-consumer stage of its life cycle (Organisation for Economic Co-operation and Development [OECD], 2024). However, traditional legacy EPR systems remain highly localized, relying on centralized domestic registries and

municipal reporting structures that are fundamentally unequipped to track products across fragmented global supply chains (OECD, 2019). Consequently, when EEE crosses international borders, the financial and regulatory links to the original producer are completely broken. The resulting regulatory vacuum shifts environmental externalized costs directly onto municipal authorities and informal workers in receiving states (Davis & Garb, 2019).

To eliminate this enforcement gap, global environmental governance must shift from insular domestic strategies toward a digitally integrated, polycentric framework. Polycentric governance involves multiple independent authorities operating across overlapping scales to enforce shared environmental standards (Ostrom, 2010). Combining digital structures specifically cryptographic tracking ledgers, digital identification systems, and geolocation smart city applications with traditional environmental law can operationalize a cross-border circular economy (Mallick et al., 2024). Combining digital structures specifically cryptographic tracking ledgers, digital identification systems, and geolocation smart city applications with traditional environmental law can operationalize a cross-border circular economy (Mallick et al., 2024). By bridging technology and international environmental law, this approach establishes a multi-layered compliance network that directly operationalizes global mandates under SDG 17 (Partnerships for the Goals) and SDG 9 (Industry, Innovation, and Infrastructure). By embedding structural regulatory data directly into these technological systems, states can seamlessly track transnational UEEE flows, enforce international tracking mechanisms, and dynamically scale enforcement parameters (World Economic Forum, 2020).

The Geographical Transferability Matrix

The operational matrix outlines how these transfer mechanisms scale across different socioeconomic landscapes. In West African Marine Hubs, such as Nigeria and Ghana, the strategy focuses on deploying Harmonized QR Ledger Networks between major shipping hubs like Lagos and Tema to combat porous land borders, pervasive customs evasion, high open-air burning rates, and the illegal misclassification of hazardous waste as functional electronics (UNEP, 2019; Global Affairs, 2023). This digital architecture mandates unique cryptographic QR codes generated at the originating port to act as digital product passports, allowing regional port alliances to verify shipments through

interconnected cloud ledgers to completely block customs shopping and minimize untracked regional spillover.

In South Asian Mega-Cities like India, policies must instead navigate a vast, deeply segmented informal collector network that currently processes 95% of regional e-waste using hazardous residential acid baths. To transition this network toward real-time market-linked compliance, the framework recommends Digital ID Tokenization (Livemint, 2026). This system utilizes existing national digital ID infrastructures to connect producer-funded cryptographic buy-back tokens directly with India's national identity database (Aadhaar), rewarding collectors digitally through basic welfare or verified accounts to safely shift localized economic scales (Diligence Certification, 2026).

Finally, Latin American Urban Centers such as São Paulo, Mexico City, and Bogotá are constrained by fragmented municipal boundaries, high consumer electronic turnover, and a lack of specialized tracking tools that leads directly to standard landfill burying. To overcome these limitations, governments should deploy Smart City Geolocation by embedding tailored e-waste reverse logistics modules directly into existing multi-utility civic applications (Sensoneo, 2024; Xavier et al., 2022). This approach optimizes urban electronics recovery by utilizing citizen crowdsourcing, automated auditing ledger compliance, and smart bin routing algorithms.

West African Marine Hubs and QR Ledger Harmonization

The West African sub-region, particularly coastal transit junctions like Nigeria and Ghana, serves as a primary destination for transboundary e-waste flows originating from the Global North. Under domestic legal regimes such as Nigeria’s National Environmental (Electrical/Electronic Sector) Regulations (2011) and Ghana’s Hazardous and Electronic Waste Control and Management Act (2016), formal EPR structures are codified but suffer from significant systemic friction (Government of Ghana, 2016; NESREA, 2011). The structural bottlenecks in these jurisdictions include highly porous territorial borders, pervasive customs evasion, misclassification of hazardous waste as functional electronics, and widespread open-air burning of cables to extract valuable scrap metals (Amoyaw-Osei et al., 2011).

Because these shipping lanes are interlinked, insular domestic enforcement inevitably triggers regional spillover. When one port introduces strict environmental monitoring, illicit shipments are simply

redirected to neighboring ports with weaker enforcement before crossing land borders undetected (Basel Convention Coordinating Centre for Africa [BCCC-Africa], 2022). To address this structural vulnerability, a digital transfer strategy based on harmonized QR ledger sharing must be deployed between major regional maritime hubs, specifically the Port of Lagos (Apapa/Tin Can Island) in Nigeria and the Port of Tema in Ghana.

Under this unified approach, incoming EEE shipments must display a secure, unique cryptographic QR code generated at the port of origin. This QR code acts as a dynamic digital passport containing verified product data, including the manufacturer's identity, component breakdown, hazardous material declarations, and the financial deposits made under the originating state's EPR system (World Economic Forum, 2020). When the shipment arrives at either Lagos or Tema, port authorities use an interconnected cloud-based ledger system to verify the authenticity of the QR tag. If a shipment is flagged as non-functional or fraudulent, the ledger automatically locks the tracking status, logs the non-compliance across both national databases, and alerts regional maritime networks to prevent customs shopping (UNEP, 2021). By creating a unified digital barrier, regional actors can eliminate the regulatory arbitrage exploited by illegal waste traders, protecting public health and securing coastal borders. Consequently, this regional port harmonization directly fulfills the mandates of SDG 12.4 by securing the environmentally sound management of transboundary hazardous waste streams, while simultaneously safeguarding coastal communities in alignment with SDG 3.9.

South Asian Mega-Cities and Digital ID Tokenization

In South Asian mega-cities, exemplified by metropolitan hubs across India, the structural challenges underlying e-waste regulation are deeply connected to complex socio-economic stratification. India's E-Waste (Management) Rules (2022) establish clear recycling targets based on EPR principles, assigning specific collection responsibilities to producers (Ministry of Environment, Forest and Climate Change [MoEF&CC], 2022). However, formal corporate collection infrastructure struggles to compete with the highly organized, decentralized informal waste sector. This informal network consists of millions of waste pickers, scrap dealers (*kabadiwalas*), and informal aggregators who process up to 95% of the state's generated e-waste (Bhartiya et al., 2023; Officers Pulse, 2023).

This informal economy is heavily segmented, operating through entrenched, marginalized community networks that function entirely outside formal tax and corporate monitoring mechanisms. Because these informal collectors provide immediate cash payments directly to consumers for obsolete electronics, they effectively outbid formal corporate collection systems (Thales Group, 2024). The collected waste is then processed within dense residential quarters using hazardous techniques, such as open acid baths to dissolve circuit boards, causing severe chemical pollution in urban water tables (Widanapathirana et al., 2023).

To build an effective policy framework, regulations must avoid punitive enforcement that criminalizes informal workers, which worsens poverty and drives processing deeper underground. Instead, policy must leverage the structural efficiency of the informal network while eliminating its environmental hazards. The recommended digital approach utilizes India's comprehensive national digital identity framework, Aadhaar, to bridge the gap between informal collection and formal, ecologically safe recycling (Rechain Technologies, 2026).

Under this framework, formal recycling centers and authorized corporate compliance units issue digital e-waste buy-back tokens to informal scrap collectors when they deposit e-waste at certified consolidation points. These cryptographic tokens represent financial incentives funded by producers through national EPR compliance structures (India Energy Solutions, 2023). By integrating this system with national digital ID registries, these buy-back tokens are deposited directly into the collectors verified bank accounts via state-backed digital payment systems (MeitY, 2024). This integration shifts the economic balance, making safe drops at formal centers more profitable than hazardous home-based acid processing. Furthermore, this token system links informal workers to state-supported social welfare programs, converting an underground environmental hazard into a formal path for socio-economic mobility. By tethering environmental compliance directly to national safety nets, the architecture advances SDG 8.8, protecting the labor rights and economic security of highly vulnerable, informal waste collectors.

Latin American Urban Centers and Smart City Geolocation Integration

Latin American metropolitan centers, such as São Paulo, Mexico City, and Bogotá, face unique structural pressures driven by rapid urbanization, high consumer technology turnover, and fragmented municipal waste frameworks. Unlike regions dominated by decentralized maritime inflows or long-standing informal collection networks, Latin American e-waste challenges stem primarily from domestic post-consumer generation. While comprehensive legal frameworks exist such as Brazil's National Solid Waste Policy [PNRS] (2010) operational execution is severely hampered by overlapping municipal jurisdictions and a lack of specialized tracking infrastructure.

The primary operational bottleneck is the absence of convenient, transparent municipal collection systems, which leads consumers to dispose of obsolete electronics alongside standard municipal solid waste. This practice results in electronic components being buried in standard sanitary landfills, leading to long-term heavy metal leaching into regional agricultural soils. To resolve these challenges, municipal governments must integrate e-waste reverse logistics systems directly into emerging smart city infrastructure.

This strategy utilizes existing municipal geolocation mobile applications, which are already used by citizens to navigate public transit, report municipal issues, or manage utility bills. By embedding an e-waste tracking module into these smart platforms, municipal authorities can crowdsource reverse logistics data. When a consumer wishes to dispose of electronic waste, they register the item on the municipal app, which uses geolocation data to direct them to the nearest certified smart collection bin or schedules a precision pickup by municipal crews.

For commercial enterprises and high-volume consumers, the application logs the transaction on a transparent municipal ledger, generating digital compliance certificates that satisfy national environmental auditing requirements. The application dynamically routes collection vehicles based on real-time fill volumes within smart bins, minimizing fuel consumption and greenhouse gas emissions associated with municipal waste management. By embedding environmental compliance into the digital infrastructure of the smart city, this model lowers participation barriers for citizens, optimizes logistics for municipal managers, and provides national regulators with transparent, audit-ready data across dense metropolitan populations. This systematic integration of real-time route optimization and localized civic crowdsourcing serves

as a benchmark for SDG 11.6, directly reducing the adverse municipal environmental impact of rapidly growing urban centers.

Conclusion

The global scale of the electronic waste crisis requires an immediate departure from insular, state-centric environmental policies toward collaborative, digitally integrated frameworks. As conceptualized through this polycentric governance model, combining Extended Producer Responsibility (EPR) with modern digital tools offers a clear pathway to enforce international environmental standards across diverse socio-legal landscapes (Ostrom, 2010; World Economic Forum, 2020). In doing so, this digital pivot provides the missing enforcement mechanism required to transition abstract United Nations Sustainable Development Goals into verifiable, localized legal compliance.

The Geographical Transferability Matrix demonstrates that successful policy diffusion depends entirely on aligning digital solutions with localized structural baselines. Whether through regional QR ledger integration at West African maritime borders, linking financial token incentives with national digital IDs in South Asia, or embedding reverse logistics into Latin American smart city platforms, technology can convert regulatory friction into cooperative environmental compliance (Dias et al., 2022; Global Affairs, 2023; Rechain Technologies, 2026). For legal scholars and international policymakers, these integrated strategies offer the structural tools necessary to manage transnational waste streams, internalize environmental externalities, and accelerate the transition toward a global, digitally verified circular economy (UNEP, 2021).

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FROM WASTE PICKERS TO GREEN WORKERS: INTEGRATING PAKISTAN'S INFORMAL RECYCLING WORKFORCE INTO THE CIRCULAR ECONOMY

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Introduction

Waste is one of the most visible sustainability challenges in Pakistan's cities. When the Punjab government launched its **Suthra Punjab program** in December 2024, officials reported that the province generated about 60,000 tons of waste every day, but only around 20,000 tons were being collected (Associated Press of Pakistan [APP], 2024). Earlier research in Lahore found that formal collection reached about 57% of waste, and coverage was even lower in other large cities (Masood et al., 2014). Uncollected waste is burned, dumped on open land, or left to block drains, which worsens air pollution and urban flooding. The problem is also growing worldwide: global municipal waste is expected to rise from 2.01 billion tons in 2016 to 3.40 billion tons by 2050 (Kaza et al., 2018).

Yet Pakistan already has a large recycling workforce. Waste pickers, door-to-door buyers, and *kabari walas* (scrap dealers) recover plastic, paper, metal, and glass and sell them back to industry. In circular economy terms, they keep materials in use instead of sending them to landfill (Kirchherr et al., 2017). Research shows that recycling in Pakistan is almost entirely informal and unregulated, and that in Lahore informal collectors reduce the waste handled by the city's waste company by an estimated 27% (Nawaz et al., 2021). However, these workers do their job without recognition, safety equipment, training, or social protection.

Drawing on a public administration and human resource management (HRM) perspective, this contribution argues that Pakistan's circular economy transition should treat waste pickers as a workforce to

be organized, trained, and protected, rather than as a problem to be removed. It reviews good practices from India and Brazil and proposes practical recommendations that build on Pakistan's current waste management reforms.

Keywords: Circular economy, informal sector, waste pickers, public administration, Pakistan.

The Policy Challenge: An Invisible Workforce Exclusion From Formal Systems

Pakistan is now modernizing waste management at a large scale. Suthra Punjab covers both urban and rural areas, employs a workforce of around 150,000 sanitation workers (Aaj News, 2025), and is backed by a newly established Suthra Punjab Authority (APP, 2025). Its next phase is moving towards recycling and converting waste into energy (The News, 2025). These are positive steps. However, the informal workers who already carry out most recycling are largely absent from the design of these systems. International evidence shows that when formal systems expand without including informal recyclers, two things happen: poor workers lose their main source of income, and cities lose a low-cost recycling service that they then have to replace at higher cost (Aparcana, 2017; Wilson et al., 2006). Masood and Barlow (2013) noted this risk in Pakistan more than a decade ago, but it has not yet been addressed in policy.

Unsafe Work and No Social Protection

Waste picking in Pakistan is often done by the poorest groups, including migrants and minorities, and sometimes by children. Workers handle sharp objects, chemicals, and medical and electronic waste with bare hands. Because their work is unregistered, they remain outside government welfare schemes and face strong social stigma, including a perception among formal actors that they are linked to theft (Nawaz et al., 2021). Many depend on scrap dealers for loans, which keeps them in a weak bargaining position.

No Data, No Skills Pathway

Finally, there is no official record of how many waste pickers exist, where they work, or how much material they recover. Without this data, local governments cannot plan for them, and their contribution to recycling is invisible in official statistics. There is also no structured way for these workers to gain skills, certification, or access to formal contracts.

From an HR perspective, this is a workforce with valuable experience but no recognition, no development pathway, and no voice.

Policy Recommendations

The following five recommendations aim to bring waste pickers into Pakistan's circular economy in a gradual, practical, and affordable way. They are designed first for Punjab, where reforms are most advanced, but can be adopted by other provinces.

Recommendation 1: Count and Recognize the Workforce

Local governments, working with the Suthra Punjab Authority, should create a free and voluntary digital registry of waste pickers and scrap collectors, linked to the national identity card system. Registered workers should receive an occupational identity card, as in Pune. This simple step gives workers legal recognition, reduces harassment, and provides the data that planners need.

Recommendation 2: Organize Workers and Include Them in Contracts

Government should help registered workers form cooperatives or associations. As Suthra Punjab moves into its recycling phase, a share of door-to-door dry waste collection and sorting work should be reserved for these groups, and space should be provided for them at transfer stations and material recovery facilities. Households should be encouraged to separate wet and dry waste, which makes recycling safer and more productive.

Recommendation 3: Build Skills and Workplace Safety

Training bodies such as the Punjab Technical Education and Vocational Training Authority (TEVTA) and the National Vocational and Technical Training Commission (NAVTTC) should offer short, practical courses on waste segregation, safe handling of electronic and hazardous waste, occupational health and safety, and basic financial literacy. Skills already gained on the job should be formally certified through recognition of prior learning. Basic protective equipment should be provided to all registered workers.

Recommendation 4: Extend Social Protection

Registered waste pickers should be linked to existing schemes rather than new ones. These include public health insurance, provincial

social security institutions, and the Benazir Income Support Program for the poorest families, including its education stipends to keep children in school instead of at work. Welfare measures already offered to sanitation workers could be extended to registered recyclers.

Recommendation 5: Use Digital Tools for Transparency and Fair Income

Simple mobile applications can let households request collection of recyclables, allow workers to receive digital payments, and record the type and weight of material recovered. These records would make informal recycling visible in official statistics, help track progress towards circular economy goals, and could support future access to carbon finance.

Implementation Pathway

These measures should start with a pilot in Lahore, where the Lahore Waste Management Company has the strongest capacity, and one smaller city, over 12 to 18 months. Progress can be measured through clear indicators: the number of registered workers, changes in their income, tons of material recovered, collection coverage, workplace injuries, and school attendance of workers' children. Successful results can then be scaled across Punjab and shared with other provinces. Because the plan relies mostly on existing institutions, its main costs are in coordination and training, which can be partly offset by lower landfill and transport costs.

Relevance and Transferability to Other Contexts

Informal waste picking is common across South Asia, Africa, and Latin America, so the lessons of this contribution apply widely. The approach is especially relevant for countries that are rapidly modernizing their waste systems through private contractors and new machinery, because this is exactly when informal workers are most at risk of being pushed out. The core idea, integrating rather than replacing informal recyclers, can be adapted to different legal systems, cooperative laws, and social protection schemes. Attention to local factors such as social stigma, gender, and child labour will be essential, but the combination of recognition, organization, skills, protection, and digital tools offers a practical model that other governments can follow.

Conclusion

Pakistan does not need to build a recycling workforce from scratch; it already has one. What is missing is recognition, protection, and a place for these workers in the formal system. By registering waste pickers, helping them organize, building their skills, extending social protection, and using digital tools, Pakistan can increase recycling, reduce pollution, and create decent green jobs at the same time. Experiences from Pune and Brazil show that this is achievable. With Suthra Punjab entering its recycling phase, now is the right moment to make Pakistan's circular economy transition both greener and fairer.

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FROM THE RIGHT TO REPAIR TO THE CIRCULAR ECONOMY: LEGAL CHALLENGES AND POLICY RECOMMENDATIONS FOR ROMANIA WITHIN THE EUROPEAN UNION

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Introduction: Repair as a Legal and Policy Challenge

The European Union's transition towards a circular economy requires more than improved waste collection and recycling. It also requires legal and economic conditions under which products remain useful for longer. Repair occupies a strategic position in this transition: it can preserve the value of a product before it becomes waste, but the consumer's decision depends on cost, convenience, trustworthy information and access to competent repair services. Research on repair policy identifies regulatory, informational and market barriers that cannot be resolved through product design alone (Svensson et al., 2018; Milios, 2018).

Romania presents a compelling policy case. According to Eurostat (2025), its circular material use rate in 2024 was 1.3%, compared with 12.2% across the European Union. This indicator measures the contribution of recycled materials to overall material use; it does not measure the frequency or effectiveness of repair. It nevertheless illustrates the need for complementary circular-economy measures, including longer product lifetimes. The present contribution examines the relevant EU legal framework, Romanian implementation challenges and an existing French incentive, then proposes measures that are legally coherent, institutionally feasible and transferable to other national contexts.

The EU Legal Framework: Rights, Product Design and Producer Responsibility

Directive (EU) 2024/1799 on common rules promoting the repair

of goods marks a significant development in European consumer law. Under Article 5, consumers may request repair from a manufacturer where, and to the extent that, repairability requirements are established by the EU legal acts listed in Annex II. Repair must be provided free of charge or at a reasonable price and within a reasonable time, unless it is impossible. The obligation is therefore product-specific, not an unrestricted right to have every defective item repaired. The Directive also addresses access to repair-related information, spare parts and tools, while restricting contractual or technological obstacles to repair that lack legitimate and objective justification (European Parliament & Council of the European Union, 2024a).

A distinction is necessary between repair outside the seller's liability and remedies for non-conforming goods. By amending Directive (EU) 2019/771, the new legislation provides for a one-time 12-month extension of the seller's liability period when repair is chosen as the remedy, subject to the applicable legal conditions. This is not a general extension for all paid repairs. The transposition and application deadline was 31 July 2026; the European online repair platform's common interface is due by 31 July 2027. Member States must also adopt at least one measure promoting repair (European Parliament & Council of the European Union, 2024a, Arts. 7, 13, 16, 22).

The European Repair Information Form adds a contractual transparency tool. Repairers may use this standardised form voluntarily to specify the defect, price and expected completion time; if issued, the stated conditions must generally remain unchanged for at least 30 calendar days. The form itself is free, although a necessary diagnostic service may be charged after the consumer has been informed of its cost. This instrument illustrates how harmonised information, rather than an additional blanket obligation, can reduce uncertainty while preserving flexibility for small repair providers (European Parliament & Council of the European Union, 2024a, Art. 4).

Regulation (EU) 2024/1781, the Ecodesign for Sustainable Products Regulation, complements these rules at the design stage. It establishes a framework for requirements concerning durability, repairability, disassembly and relevant product information, including digital product passports under product-specific implementing arrangements. It would be inaccurate to describe all digital product passports as already compulsory for every good. Together, the Directive

and Regulation connect consumer remedies, manufacturers' obligations and product design. They also require attention to legitimate safety and intellectual-property interests without allowing such interests to become an automatic justification for excluding independent repairers (European Parliament & Council of the European Union, 2024b).

Extended producer responsibility (EPR) adds an institutional dimension. Empirical research on white goods shows that collection and recycling systems do not automatically generate incentives for repair or reuse; access to reusable products, cooperation among actors and suitable financing arrangements matter (Dalhammar et al., 2021). A comparative study of the waste-electrical-and-electronic-equipment framework likewise identifies fragmented national reporting and varying producer obligations (Andersen, 2022). Romania should therefore connect repair promotion to EPR practice without assuming that all existing waste-management funds may automatically be redirected to subsidies.

Romania: From Strategic Commitments to Effective Access

Romania adopted its National Circular Economy Strategy through Government Decision No. 1172/2022 and added an Action Plan through Government Decision No. 927/2023 (Government of Romania, 2022, 2023). These instruments provide a policy framework for resource efficiency, sectoral action and cooperation among public institutions and economic actors. They should be read alongside applicable consumer-protection and EU product legislation rather than treated as a substitute for enforceable private-law rights.

The immediate challenge is practical implementation. A legal entitlement may have little effect where consumers cannot compare repair offers, diagnostic costs are unclear, parts are unavailable or services are concentrated in larger cities. Smaller repair businesses may face difficulties with training, registration and administrative procedures. These are policy risks requiring territorial assessment, not statistical findings established by the present contribution. Equally, the state of Romanian transposition and enforcement should be assessed against the legislation and official notifications currently in force, rather than inferred from obsolete discussions of proposals made before 2024.

The legal response must identify who is responsible for the remedy: the seller during the relevant consumer-sales liability period, the manufacturer under the separate EU repair obligation, or an independent repairer under an agreed service contract. Clear allocation of duties,

transparent pre-contractual information and accessible dispute resolution are central to consumer confidence and fair competition.

Good Practice: France's Repair Bonus

France's bonus réparation offers a useful illustration of how a legal objective can become a visible market incentive. For eligible categories, a consumer receives a reduction directly on the repair invoice when using a labelled repairer. The scheme is financed by producer contributions channelled through approved EPR organisations, rather than relying on a later reimbursement claim by the consumer (French Ministry of Economy, 2026). Its transferable strength is not a particular subsidy amount, but the combination of an immediate price signal, recognisable providers and administrative simplicity.

Transfer to Romania would require adjustment for national market structure, eligibility rules, funding arrangements and the availability of repairers in smaller localities. A Romanian scheme should not presume that accreditation, subsidies or environmental savings are costless: each requires transparent criteria and evaluation. The French example is consequently a design reference, not evidence that identical outcomes would follow in every Member State.

Policy Recommendations for Romania

First, establish a single public information gateway on repair rights. The competent consumer-protection authority, working with relevant ministries, should publish plain-language explanations distinguishing seller liability, manufacturers' repair obligations and independent repair contracts. Retailers and repairers could receive model notices and a standard checklist on diagnostic charges, indicative completion times and complaint channels. Information should remain accessible both online and through local assistance points. Success could be assessed through website use, consumer comprehension surveys and complaint-resolution times.

Second, pilot an invoice-based repair incentive in selected counties. The ministries responsible for environment and the economy could examine a limited programme for eligible out-of-guarantee household electrical and electronic goods, developed with participating EPR organisations where legally permissible. Discounts should be visible immediately on invoices, with proportionate accreditation requirements, published eligibility criteria and safeguards against inflated prices or

double funding. A controlled pilot should measure uptake and unit cost before any national expansion.

Third, support a geographically inclusive repair network. Public authorities and professional associations should help independent and authorised repairers join the forthcoming European repair platform or a compliant national alternative. Registration must remain voluntary as required by the Directive, while assisted digital onboarding and accessible information can reduce disadvantages for micro-enterprises. Coverage should be monitored by county and by product category so that improved digital visibility does not conceal territorial gaps.

Fourth, strengthen practical compliance and skills. Consumer authorities, vocational schools, universities and repair associations could prepare short training modules on lawful diagnostic fees, product safety, transparent contracts, available repair information and fair dispute resolution. A particular priority is explaining when manufacturers may legitimately invoke safety or intellectual-property restrictions and when repair barriers may be unjustified under EU law. Standardised documents and affordable courses would be more proportionate for small providers than complex new reporting duties.

Fifth, integrate repair and reuse with producer-responsibility governance. Within the limits of waste and product law, public authorities should encourage agreements among EPR organisations, municipalities, reuse centres and qualified repairers for the identification and transfer of suitable products. Access criteria, ownership, liability, data protection and safety checks must be explicit. Experience with white goods indicates that operational coordination, rather than the mere existence of an EPR scheme, is decisive for higher-value circular activities (Dalhammar et al., 2021).

Sixth, adopt a public monitoring framework. An annual dashboard should distinguish programme outputs (registered repairers and completed repairs) from outcomes (repair cost, consumer satisfaction, repeat failure and estimated product-life extension). Indicators should be disaggregated by region and product type. Any estimate of avoided emissions or material savings must use an explicit life-cycle method and account for replacement effects; it should not be derived mechanically from Eurostat's circular material use rate. An independent evaluation after two years could guide continuation, revision or termination of incentives.

Transferability and Conclusion

Implementation should be phased. An initial administrative review should map applicable obligations, existing repair services and the availability of product-specific parts and information. The following phase could test information materials and targeted financial incentives in urban and rural localities. Only after an independently assessed pilot should any permanent scheme be scaled. This sequencing helps distinguish a failure of legal awareness from a lack of viable service capacity and avoids committing public resources to a nationwide subsidy before its effectiveness is demonstrated.

The proposed framework can be adapted by other EU Member States and, with appropriate legal adjustments, neighbouring countries. Its transferable elements are the separation of legal rights from economic incentives, simple consumer-facing information, proportionate access for local repair businesses, coordination with producer responsibility and measurable public outcomes. The precise institutions, funding models and product priorities must remain sensitive to national resources and market conditions.

The right to repair is most effective when legal entitlement becomes a realistic consumer choice. For Romania, the priority is not to multiply general declarations on sustainability, but to connect harmonised EU rules and existing circular-economy commitments with affordable services, clear accountability and verifiable results. Such an approach treats repair simultaneously as a consumer-law guarantee, an opportunity for small enterprises and a practical instrument of the green and digital transition.

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UKRAINIAN EXPERIENCE IN DEVELOPING A CIRCULAR ECONOMY

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Abstract

The transition from a linear to a circular economy has become a key policy priority for Ukraine, aligning environmental goals with economic resilience, European integration, and post-war reconstruction. Ukraine's experience is particularly relevant as the country simultaneously reforms its waste management system, restores damaged infrastructure, and seeks to reduce its reliance on virgin resources. This article examines the current regulatory framework and emerging circular economy practices in Ukraine, focusing specifically on waste management, resource-efficient production, industrial symbiosis, agriculture, and reconstruction processes. The analysis indicates that Ukraine has shifted from fragmented circular economy initiatives to a more holistic public policy system, culminating in the adoption of the Circular Economy Development Strategy for Ukraine through 2035. However, implementation is hindered by factors such as inadequate infrastructure, a lack of investment, institutional fragmentation, limited secondary raw material markets, and weak monitoring capabilities. The article proposes practical policy measures to accelerate implementation and identifies elements of the Ukrainian experience that could be applied in other countries facing challenges related to reconstruction, resource scarcity, or rapid institutional transformation.

Keywords: circular economy, Ukraine, waste management, post-war reconstruction, resource efficiency.

Ukrainian Experience in Developing a Circular Economy

The circular economy represents a shift from the traditional "take-make-dispose" model toward systems that reduce resource consumption, extend product lifespan, reuse products and components, and return materials to productive use. For Ukraine, circularity has taken on strategic significance, as environmental degradation, supply chain disruptions, infrastructure destruction, and resource constraints intersect with the country's European integration agenda. Ukrainian researchers emphasize that developing a circular economy can simultaneously support resource efficiency, competitiveness, environmental protection, and post-war recovery (Horbal & Slipachyk, 2024; Shpak et al., 2020).

The policy landscape has changed significantly in recent years. The Law of Ukraine "On Waste Management" established a new system based on the waste hierarchy, strategic planning, and European waste management approaches. The National Waste Management Plan through 2033 subsequently provided a framework for regional and local planning, while the Circular Economy Development Strategy of Ukraine through 2035 expanded the policy agenda beyond waste management to encompass eco-design, resource efficiency, circular business models, secondary raw materials, and closed-loop value chains. The primary political challenge lies in the gap between the new regulatory framework and the capacity to implement circular solutions at the national, regional, and enterprise levels. Ukraine’s waste management system has historically focused on disposal rather than prevention, reuse, and material recovery. Academic research identifies several interconnected barriers: regulatory inconsistencies, inadequate state support mechanisms, high initial costs for green technologies, limited environmental awareness, and insufficient incentives for businesses and consumers (Hlushchenko, 2025). Similarly, Mazur (2025) argues that the Ukrainian economy remains predominantly linear and that waste management reform must be accompanied by economic and technological measures that support reuse and recycling.

Therefore, the challenge extends beyond merely building more recycling facilities. A functioning circular economy requires improvement markets for secondary materials, predictable regulation, financing mechanisms, eco-design requirements, reliable data, appropriate skills, and collaboration among municipalities, businesses, researchers, and financial institutions.

Ukrainian Policy and Institutional Experience

A significant step forward was the adoption of the National Waste Management Plan until 2033. The Plan establishes a framework for national, regional, and local waste-management planning and includes targets for separate collection, recycling, waste prevention, biological waste management, and construction and demolition waste. The policy framework envisages, among other objectives, wider separate collection and preparation of municipal waste for reuse and recycling, as well as recovery of construction and demolition materials.

The next major development was the adoption on September 17, 2026, of the Strategy for the Development of the Circular Economy of Ukraine until 2035 and its 2026–2028 operational plan. The Strategy explicitly recognizes that circular economy policy should extend beyond waste management to the entire life cycle of products, including eco-design, production, consumption, reuse, recycling, and recovery. It also provides for national methodological guidance aligned with the ISO 59000 series, development of circular-economy monitoring, improved statistical data, and stronger coordination between national and local authorities.

This institutional development is particularly important because it creates a policy bridge between environmental regulation and economic development. It also supports Ukraine's European integration: the European Union's Ukraine Facility identifies circular economy reform and waste-management planning among the country's green-transition commitments.

Emerging Good Practice

The Ukrainian experience demonstrates that circular solutions can develop even before a comprehensive national policy framework is fully operational. The Resource Efficient and Cleaner Production Centre has documented Ukrainian company cases involving renewable resources, resource-efficient production, industrial symbiosis, reuse, refurbishment, recycling, and waste valorization (Resource Efficient and Cleaner Production Centre, 2024). One notable example is **Goodvalley Ukraina**, where agricultural and livestock residues are processed through anaerobic digestion to produce biogas. The resulting energy is used for electricity and heat generation, while the remaining biomass is returned to agricultural production as organic fertilizer. This demonstrates a relatively closed biological cycle in which waste from one stage of

production becomes an input for another. Another example is **Ochis**, which uses coffee grounds collected from cafés in Kyiv as a material for producing eyewear. This illustrates the ability of small and medium-sized enterprises to transform local waste streams into products with higher added value. Similarly, the Ukrainian garment company **Parada** installed a 100 kW rooftop solar power plant, thereby increasing its energy autonomy and reducing its reliance on the municipal power grid.

Such cases show that circularity is not limited to municipal recycling. It can involve renewable energy, industrial resource efficiency, product redesign, local material cycles, and new business models. The Ukrainian experience therefore supports a multi-sectoral interpretation of the circular economy. Other studies indicate that the development of circular agriculture can also combine resource conservation, agroecological practices, waste utilization, and soil restoration with digital technologies for resource monitoring and production optimization (Dimov et al., 2024; Dovgal et al., 2024).

Post-war reconstruction creates an additional opportunity. Construction and demolition waste, scrap metals, damaged infrastructure components, and other materials can potentially become secondary resources rather than being sent to disposal sites. Recent research proposes integrating sorting, material recovery, recycling, industrial symbiosis, and digital monitoring into reconstruction policy (Lutsenko, 2026).

Practical Policy Recommendations

First, make circularity a mandatory criterion for reconstruction investment. Publicly and internationally financed reconstruction projects should evaluate material reuse, recycled-content requirements, repairability, life-cycle costs, and waste prevention alongside conventional cost and technical criteria. This would prevent the reconstruction process from reproducing the linear economic model.

Second, it is necessary to establish effective markets for secondary raw materials. Ukraine should introduce quality standards and a digital system for tracking the origin of recycled materials, set clear criteria for determining the point at which waste ceases to be classified as waste ("end-of-waste"), and leverage public procurement mechanisms to generate demand for secondary materials. Construction and infrastructure projects could serve as the first large-scale market for recycled aggregates, metals, and other recovered resources.

Third, combine extended producer responsibility with eco-design. Producer responsibility cannot be limited to financing waste collection. It should incentivize the creation of products that are durable, repairable, reusable, and recyclable, and that contain recycled materials. Such an approach would shift the policy focus from end-of-life waste management to waste prevention at the design stage.

Fourth, develop regional circular-economy platforms. Municipalities and regions should map local material flows and identify potential connections between companies. Agricultural residues, food waste, industrial by-products, construction materials, and waste heat can become inputs for other economic activities. Such platforms could gradually develop into industrial-symbiosis networks.

Fifth, link circular economy policy with digitalization. A national material-flow information system could provide data on waste generation, secondary raw materials, infrastructure, and business demand. Digital tools can improve traceability and resource management in agriculture and industrial production (Dimov et al., 2024).

Countries affected by war or natural disasters, or those undergoing large-scale infrastructure transformation, can adapt the Ukrainian approach by combining reconstruction funding with circular procurement principles, material recovery, local industrial symbiosis, and waste prevention requirements. The key element to adopt is not a specific technology, but rather the integration of circular economy principles into the reconstruction management system from the beginning.

Conclusion

Ukraine has moved from isolated circular-economy initiatives toward an increasingly comprehensive policy system. The Waste Management Law, the National Waste Management Plan until 2033, practical business cases, international technical assistance, and the 2026 Strategy for the Development of the Circular Economy until 2035 together form the foundations of a national circular transition.

Thus, the implementation of circular economy policies should be viewed as a tool for economic development and reconstruction, rather than merely as an environmental policy. The most promising opportunities for Ukraine lie in the areas of construction and demolition waste recycling, the use of agricultural biomass, resource-efficient production, eco-design, and circular public procurement. Practical

implementation will be the decisive factor, requiring stable regulation, financing, measurable targets, reliable data, and coordination across various levels of government and along value chains.

For other countries, Ukraine is a clear example of how circular economy principles can be integrated into recovery policies. The key lesson to be drawn is the need to shape infrastructure, markets, institutions, and investment mechanisms in a way that keeps resources in productive use for as long as possible.

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ARTIFICIAL INTELLIGENCE AND THE CIRCULAR ECONOMY IN AFRICA: ADVANCING SUSTAINABLE DIGITAL GOVERNANCE UNDER AFRICAN UNION FRAMEWORK

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Abstract

The African Union's emerging approach to artificial intelligence (AI) governance reflects a recognition that AI will play a central role in Africa's digital transformation, economic integration, and sustainable development agenda. At the same time, African economies face increasing pressure to adopt circular economy models to address resource scarcity, ecological degradation, electronic waste, and structural inequalities in digital markets. This paper examines the intersection of artificial intelligence, law, the digital economy, and the circular economy through the lens of the African Union's AI policy framework and broader continental development strategies, including Agenda 2063 and the African Continental Free Trade Area (AfCFTA).The paper argues that AI has the potential to accelerate Africa's transition toward a circular digital economy by enabling smarter resource management, sustainable agriculture, predictive maintenance, waste reduction, financial inclusion, and more efficient cross-border trade systems. AI technologies can support data-driven environmental governance and foster innovation ecosystems across emerging African digital markets. However, the rapid deployment of AI also raises serious legal and regulatory concerns regarding data governance, digital sovereignty, algorithmic bias, unequal access to technology, labour displacement, cybersecurity, and the concentration of digital power among global technology actors. Using a doctrinal legal and policy methodology, the study analyses the African Union's evolving AI governance principles alongside relevant regional instruments on digital trade, data protection, sustainability, and

innovation policy. The paper also evaluates how African legal systems can balance technological innovation with environmental sustainability, human rights protections, and inclusive economic development. Particular attention is given to the challenge of regulating AI in contexts marked by uneven digital infrastructure, fragmented regulatory systems, and dependency on externally developed technologies. The paper concludes that Africa's AI governance framework presents an opportunity to develop a uniquely African model of responsible and sustainable digital transformation. It proposes a "circular AI governance" approach grounded in digital sovereignty, regional cooperation, sustainability-by-design, ethical AI principles, and inclusive economic participation. Such a framework could strengthen Africa's position within the global digital economy while advancing environmentally sustainable and socially equitable development across the continent.

Keywords: Artificial Intelligence, Circular Economy, Digital Governance, African Union, Sustainable Development

1. Introduction

Artificial intelligence (AI) offers opportunities to advance Africa's circular digital economy through resource efficiency, sustainable innovation, and waste reduction. However, effective governance is necessary to address environmental risks, data protection, and digital inequality and is the main focus of this paper.

2. Policy Challenge: Aligning Artificial Intelligence With a Circular Digital Economy

Africa's digital transformation presents an opportunity to combine technological innovation with resource efficiency, environmental protection, and inclusive economic development. Artificial intelligence (AI) can improve agricultural productivity, optimise energy consumption, extend product lifespans through predictive maintenance, strengthen waste collection, and facilitate cross-border digital trade. However, these benefits are not automatic. AI also depends on energy-intensive computing infrastructure, critical minerals, electronic equipment, extensive data collection, and supply chains that can reproduce existing economic inequalities.

The African Union's (AU) *Continental Artificial Intelligence Strategy* provides an important foundation for addressing these

challenges. Endorsed by the AU Executive Council in July 2024, the Strategy promotes an Africa-centred, development-oriented approach to ethical, responsible, and equitable AI adoption (African Union [AU], 2024a). Its objectives complement Agenda 2063, the Digital Transformation Strategy for Africa 2020–2030, and the AU Data Policy Framework, which collectively emphasise inclusive growth, innovation, digital rights, and continental economic integration (AU, 2015, 2020, 2022).

The central policy challenge is to ensure that AI supports a *circular digital economy* rather than accelerating a linear model of resource extraction, consumption, and disposal. A circular digital economy uses digital technologies to reduce material consumption, extend the useful life of products, recover valuable resources, and promote repair, reuse, refurbishment, and recycling. The concept therefore connects AI governance with environmental law, data protection, industrial policy, labour rights, and regional trade integration.

Africa's regulatory landscape remains uneven. Differences in digital infrastructure, national data protection laws, technical capacity, and environmental enforcement can make it difficult to establish consistent safeguards across borders. Meanwhile, dependence on foreign cloud services, computing infrastructure, AI models, and digital platforms raises questions about technological sovereignty and the distribution of economic value. The policy priority should consequently be to translate the AU's existing legal and policy commitments into coordinated, enforceable, and environmentally responsible national and regional measures.

3. Existing African Union Frameworks and Policy Experience

3.1. Continental AI governance and development priorities

The AU Continental AI Strategy establishes the principal policy foundation for responsible AI development in Africa. It identifies AI as an instrument for socioeconomic transformation while recognising the importance of ethical governance, institutional capacity, skills development, innovation, and cooperation (AU, 2024a). For circular economy policy, these commitments should extend beyond the accuracy and safety of AI systems to include their environmental footprint, lifecycle impacts, and contribution to resource efficiency.

Agenda 2063 reinforces this approach through its vision of an integrated, prosperous, and peaceful Africa driven by its citizens (AU, 2015). Its emphasis on sustainable development, industrialisation, and economic integration provides a basis for treating circular AI as a development instrument rather than merely a technological objective. The Second Ten-Year Implementation Plan for 2024–2033 offers a further opportunity to incorporate measurable targets for sustainable digital infrastructure, responsible innovation, and environmentally sound industrial development (AU, 2024b).

The Digital Transformation Strategy for Africa 2020–2030 similarly identifies digital infrastructure, digital industry, digital trade, digital skills, and sectoral applications as important foundations of continental transformation (AU, 2020). Its implementation should be linked to environmental performance indicators, including energy efficiency, equipment longevity, repairability, and electronic-waste recovery.

3.2. Data governance, privacy, and digital sovereignty

The AU Data Policy Framework seeks to harmonise data governance, promote a trusted digital environment, protect digital rights, and support an inclusive and sustainable digital economy (AU, 2022). This framework is particularly relevant because AI systems rely on data generated by individuals, businesses, public institutions, agricultural systems, and environmental monitoring networks.

The *African Union Convention on Cyber Security and Personal Data Protection* (Malabo Convention) establishes continental obligations concerning personal data protection, electronic transactions, and cybersecurity (AU, 2014). Its implementation, alongside national data protection legislation, is essential to ensuring that AI-enabled circular economy applications do not expose workers, consumers, informal waste collectors, or small businesses to unlawful surveillance and misuse of personal information.

Digital sovereignty should not be equated with complete data localisation. Instead, it should involve the capacity of African states and communities to determine how data are governed, how public interests are protected, and how economic benefits are distributed. Interoperable safeguards, lawful cross-border data transfers, transparent procurement, and African research capacity can advance these objectives while enabling continental collaboration.

3.3. Digital trade and regional economic integration

The Agreement Establishing the African Continental Free Trade Area (AfCFTA) provides a framework for expanding intra-African trade and economic integration (AU, 2018). Its Protocol on Digital Trade, adopted on 18 February 2024, seeks to establish common principles and harmonised rules for secure, inclusive, and sustainable digital trade, including cooperation on emerging technologies and digital innovation (AU, 2024c).

These instruments can support regional markets for refurbished electronic equipment, recycled materials, repair services, digital product passports, and AI-enabled waste management. Common standards would make it easier for enterprises to verify product histories, exchange relevant data, identify reusable components, and participate in cross-border circular supply chains.

Nevertheless, regulatory harmonisation must not become a mechanism for weakening privacy, environmental protection, or consumer rights. Digital trade arrangements should preserve legitimate public-interest regulation and facilitate participation by micro, small, and medium-sized enterprises.

3.4. Environmental protection and electronic waste

The *Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa* establishes a regional legal framework for addressing hazardous waste, including its transboundary movement and management (Organization of African Unity [OAU], 1991). The Revised African Convention on the Conservation of Nature and Natural Resources further provides a continental foundation for environmental conservation and the sustainable use of natural resources (AU, 2003).

These instruments are relevant to AI hardware, discarded computing equipment, batteries, telecommunications infrastructure, and other electronic waste. AI-enabled systems can improve waste identification, collection-route optimisation, material sorting, and environmental monitoring. However, technological interventions cannot replace effective waste regulation, safe working conditions, producer responsibility, or appropriate treatment facilities.

A circular AI policy should therefore connect digital innovation with existing environmental obligations. This requires assessing

equipment and infrastructure throughout their life cycles, from mineral extraction and manufacture to energy consumption, repair, reuse, and final disposal.

4. Good Practice and Emerging Opportunities

A useful policy direction is to develop locally appropriate, AI-enabled circular economy initiatives that combine digital innovation with environmental regulation and inclusive business models.

In agriculture, AI-assisted forecasting and precision farming can improve water use, reduce avoidable input consumption, and support the recovery of agricultural residues. Such applications should be developed with farmers and local research institutions, using accessible tools and contextually relevant datasets.

In manufacturing and public infrastructure, predictive maintenance can identify equipment failures before they occur, extending the useful life of machinery, transport systems, and energy infrastructure. Digital product records can also help businesses document component origins, repair histories, and opportunities for refurbishment.

In waste management, computer vision and sensor-based systems can assist with material classification, collection planning, and identification of recyclable products. These technologies could support municipal authorities and recycling enterprises, including informal waste workers, provided that deployment includes worker consultation, fair remuneration, occupational safety, and safeguards against exclusion.

These are promising applications rather than evidence that AI automatically produces circular outcomes. Their transferability depends on reliable electricity, connectivity, affordable equipment, technical skills, access to finance, and enforceable environmental standards. Governments should therefore evaluate pilot projects against measurable environmental and social outcomes before scaling them.

5. Key Legal and Regulatory Gaps

Despite the breadth of existing AU frameworks, important implementation gaps remain.

First, the Continental AI Strategy is a policy framework rather than a binding continental AI treaty. Its effectiveness depends on national legislation, institutional coordination, funding, and regulatory enforcement. States should avoid treating AI ethics as a substitute for

enforceable obligations concerning privacy, discrimination, environmental harm, and consumer protection (AU, 2024a).

Second, environmental impacts are insufficiently integrated into AI governance. The energy consumption of data centres, the extraction of minerals for digital equipment, and the disposal of obsolete hardware can undermine sustainability objectives. The Bamako Convention and the Revised African Convention on the Conservation of Nature and Natural Resources provide relevant legal foundations, but implementation must extend to the entire digital technology lifecycle (AU, 2003; OAU, 1991).

Third, fragmented national data and digital trade rules can obstruct regional circular supply chains. The AU Data Policy Framework and AfCFTA Digital Trade Protocol provide a basis for cooperation, but interoperability requires practical standards, regulatory capacity, and mutual trust (AU, 2022, 2024c).

Fourth, unequal access to infrastructure and innovation risks concentrating benefits among large technology companies. Without investment in local research, digital skills, affordable connectivity, and small-enterprise participation, AI adoption may deepen existing inequalities. The newer Science, Technology and Innovation Strategy for Africa (STISA-2034) reinforces the importance of African scientific capacity and innovation-led development (AU, 2025).

Finally, algorithmic bias and labour displacement require specific safeguards. AI systems used in recruitment, credit scoring, waste collection, or access to public services may disadvantage vulnerable groups where training data are incomplete or unrepresentative. Effective governance must therefore combine human oversight, accessible complaints procedures, impact assessments, and meaningful participation by affected communities.

6. Actionable Policy Recommendations

The following recommendations translate existing continental commitments into practical measures for governments, regional economic communities (RECs), regulators, businesses, and development partners.

- First is to establish a circular AI governance framework.

The AU Commission should develop implementation guidance connecting the Continental AI Strategy with the AU Data Policy

Framework, Agenda 2063, environmental conventions, and AfCFTA instruments. Member States should adopt corresponding national frameworks that require proportionate assessments of human rights, environmental impacts, cybersecurity, and socioeconomic risks.

High-impact AI applications should be subject to documented risk assessments, independent evaluation where appropriate, transparency obligations, and accessible remedies. This approach would provide a common continental direction without requiring every state to adopt identical legislation.

- Second is to introduce sustainability-by-design requirements.

Governments should incorporate environmental criteria into public procurement and AI infrastructure policies. Relevant criteria should include energy efficiency, renewable-energy use where feasible, equipment durability, repairability, reuse, recyclability, and responsible disposal.

AI developers and operators should disclose appropriate information about energy consumption and material impacts, proportionate to the scale and risk of their operations. Public authorities should also promote modular equipment, longer hardware replacement cycles, and refurbishment markets. These measures would operationalise the sustainability objectives of Agenda 2063 and the environmental protections reflected in the Bamako Convention and the Revised African Convention on the Conservation of Nature and Natural Resources (AU, 2003, 2015; OAU, 1991).

- Third is to harmonise data governance and enable responsible data sharing.

The AU Commission, RECs, and national data protection authorities should cooperate on interoperable standards for cross-border data transfers, AI training datasets, cybersecurity, and privacy-preserving data sharing. Implementation should build on the Malabo Convention, the AU Data Policy Framework, and the AfCFTA Digital Trade Protocol (AU, 2014, 2022, 2024c).

Regional data-sharing arrangements could support waste tracking, environmental monitoring, circular product records, and cross-border recycling markets. They should include safeguards for personal data,

commercially sensitive information, Indigenous and community interests, and equitable access to the value generated from data.

- Fourth is to strengthen electronic-waste regulation and producer responsibility.

Member States should strengthen extended producer responsibility schemes requiring manufacturers and importers to contribute to the collection, repair, refurbishment, and environmentally sound treatment of discarded electronic equipment. Customs authorities and environmental regulators should improve cooperation to prevent unlawful waste transfers and distinguish legitimate second-hand equipment from waste shipments.

Digital tracking systems, including AI-assisted monitoring, could support enforcement. However, these systems should complement physical inspections, laboratory testing, and effective penalties rather than replace them. Informal waste workers should be integrated into formal collection and recycling systems through training, protective equipment, fair compensation, and social protection.

- Fifth is to invest in African innovation and inclusive skills development.

Governments, universities, research institutions, and private enterprises should establish collaborative programmes for locally developed AI applications addressing water management, sustainable agriculture, renewable energy, repair services, and waste recovery. Funding mechanisms should prioritise African small and medium-sized enterprises, women-led businesses, young innovators, and community-based enterprises.

STISA-2034 provides a useful policy foundation for strengthening research and innovation capacity (AU, 2025). Governments should complement research funding with accessible computing facilities, open standards, local-language datasets, vocational training, and opportunities for technology transfer. Public procurement should encourage interoperable solutions and reduce unnecessary vendor dependence.

- Sixth is to create measurable implementation and accountability mechanisms.

The AU Commission and RECs should develop a monitoring framework with indicators covering both digital development and

circularity. Possible indicators include the proportion of public-sector AI projects subject to environmental and human rights impact assessments, energy use and emissions associated with publicly funded digital infrastructure and electronic equipment collected, repaired, refurbished, and recycled through compliant systems. Others are participation of small enterprises, women, young people, and informal-sector workers in circular digital value chains, cross-border interoperability of relevant data governance and digital trade systems and reported algorithmic harms and the effectiveness of complaint and remedy mechanisms.

Member States should publish periodic implementation reports and exchange lessons through AU coordination mechanisms. Pilot projects should be evaluated independently, with successful models adapted to local legal, economic, and infrastructural conditions.

7. Transferability and Relevance to Other Contexts

The proposed approach is transferable beyond Africa because it connects AI accountability with lifecycle resource management, regional integration, and inclusive innovation. The European Union, for example, offers experience in product sustainability regulation, data governance, and risk-based AI regulation. However, direct transplantation of external regulatory models would be inappropriate without considering African infrastructure constraints, institutional capacity, development priorities, and informal economic activity.

Africa's comparative opportunity lies in developing governance arrangements that are proportionate, development-oriented, and grounded in existing framework (Sanni et al 2025). To that end regional economic communities could begin with voluntary technical standards and shared pilot programmes before progressing towards more formal regulatory cooperation. Countries with stronger regulatory and research capacity could support neighbouring states through training, shared infrastructure, and technical assistance.

This model could also inform other developing regions facing similar challenges involving imported technologies, electronic waste, fragmented markets, and limited regulatory resources. Its transferability rests on adapting common principles to local conditions rather than assuming that one regulatory model will work everywhere.

8. Conclusion

The AU Continental AI Strategy creates an important opportunity to connect Africa's digital transformation with circular economy principles. Read alongside Agenda 2063, the Digital Transformation Strategy for Africa, the AU Data Policy Framework, the Malabo Convention, the AfCFTA Digital Trade Protocol, and continental environmental instruments, it provides a substantial foundation for responsible and sustainable digital development.

Nevertheless, the existence of these frameworks does not guarantee effective implementation. African governments must address regulatory fragmentation, environmental externalities, unequal technological capacity, algorithmic discrimination, and dependence on externally controlled digital infrastructure.

A circular AI governance approach should therefore combine sustainability-by-design, responsible data governance, regional cooperation, electronic-waste regulation, local innovation, and inclusive economic participation. By embedding these priorities in national laws, procurement rules, institutional arrangements, and measurable implementation plans, African states can turn AI into a practical instrument for resource efficiency and sustainable development. This approach offers a transferable policy model for aligning technological progress with environmental responsibility, social justice, and economic resilience.

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THE POLITICAL ECONOMY OF CIRCULARITY: FROM NATIONAL STRATEGIES TO GLOBAL TRADE REALIGNMENT

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Abstract

Circular economy policies have acquired a strategic significance that extends beyond environmental governance. The concentration of critical raw material supply, changing industrial priorities, and the growing influence of sustainability standards have placed circularity within the political economy of international trade. This chapter examines how national circular economy strategies interact with industrial competitiveness, regulatory influence, and the reorganization of global value chains. Selected policy experiences from the European Union, the Netherlands, and international raw-material partnerships provide the basis for discussing smart power, friend-shoring, near-shoring, and emerging trade alignments. Particular attention is devoted to the distribution of industrial value and the macroeconomic implications of material dependence. The chapter argues that circularity changes the structure of economic interdependence rather than removing it. Its contribution to economic resilience rests on the development of domestic productive capabilities alongside diversified international cooperation. Policy recommendations emphasize resource security, regulatory interoperability, and the equitable distribution of benefits from twin transition.

Keywords: Circular economy; international trade; strategic autonomy; friend-shoring; smart power.

1. Introduction

The geography of material supply has regained prominence in international economic policy. Industrial decarbonization, electrification, and digital infrastructure have intensified demand for minerals and processed materials whose production remains geographically concentrated. As documented by the International Energy Agency (IEA, 2025), critical mineral refining has become increasingly concentrated, while the diversification expected from announced projects remains limited. Access to these resources has consequently become an increasingly important consideration in industrial planning.

The economic problem extends beyond the availability of raw materials. Concentration at particular stages of processing creates dependencies throughout international production networks. Even economies with diversified import relationships remain exposed when their suppliers rely on the same refining facilities or technologies. Such vulnerabilities are transmitted through intermediate input costs, production constraints, and investment decisions.

Circularity enters this discussion by changing how materials are retained and reused within production systems. Recovery, remanufacturing, and product-life extension reduce the need for selected primary inputs. Yet the capacity to recover materials is unevenly distributed. Processing technologies, industrial infrastructure, and technical knowledge determine whether recovered resources become commercially viable substitutes.

This raises a central issue for political economy. Reducing dependence on primary resources does not necessarily reduce dependence on foreign technologies, processing capabilities, or regulatory systems. In some sectors, circular production relocates rather than resolving existing economic vulnerabilities.

National circular economy strategies must therefore be examined in relation to international specialization and the distribution of productive capabilities. Decisions concerning recycling investment, product regulation, and material security influence the organization of trade. They also affect which economies capture value from the recovery and processing of resources.

This chapter approaches circularity as a changing framework of economic interdependence. Its emphasis is on the relationship between

national policy choices, international trade arrangements, and macroeconomic resilience. The analysis draws on documented policy experiences to identify the opportunities and tensions associated with this transition.

2. National Circular Economy Strategies and the Economics of Resource Dependence

Circular economy strategies respond to different economic pressures. Import-dependent manufacturing economies seek more reliable access to industrial inputs. Resource-producing countries face the challenge of retaining greater value from extraction and processing. Economies specializing in advanced manufacturing have a further interest in technologies that support material efficiency and product recovery.

These distinctions are frequently obscured when circularity is presented as a common environmental policy agenda. Similar instruments serve different economic purposes across countries. Recycling incentives, industrial symbiosis programs, and product-design requirements must be understood in relation to domestic production structures.

The Netherlands offers an example of circularity being incorporated into long-term resource planning. Its National Circular Economy Program 2023–2030 places material consumption, environmental pressures, and supply security within a common policy framework (Ministry of Infrastructure and Water Management, 2023). The significance of this approach lies in its recognition that resource efficiency and industrial competitiveness belong to the same economic policy discussion.

For a highly trade-integrated economy, however, reducing material dependence cannot be equated with withdrawing from international markets. Domestic recovery systems operate alongside imported inputs, foreign technologies, and cross-border industrial networks. The economic advantage lies in expanding supply options and improving material productivity, not in eliminating trade.

The European Union's Critical Raw Materials Act reflects a related concern. It links extraction, processing, recycling, and supplier diversification within a strategic framework for material security (European Parliament & Council of the European Union, 2024a).

Recycling is treated as an element of industrial capacity rather than a separate waste-management activity.

The distinction between capacity and effective supply deserves attention. Investment in recovery infrastructure does not guarantee that recovered materials will enter domestic manufacturing. Commercial use depends on material quality, processing technologies, industrial demand, and relative costs. A strategy focused primarily on collection or installed recycling capacity risks overlooking these relationships.

National circular economy policy should therefore begin with the structure of material dependence. Where supply vulnerabilities arise from imported primary inputs, secondary-material production deserves consideration. Where dependence is concentrated in processing technologies, investment priorities must extend to industrial capabilities and technical expertise.

There is little economic justification for treating domestic production as an end in itself. Strategic value arises when circular capabilities strengthen supply reliability and productive efficiency without imposing disproportionate costs on downstream industries.

3. Regulatory Influence and the International Political Economy of Circularity

The international consequences of circular economy policy are not confined to material trade. Product regulation increasingly determines the conditions under which firms participate in foreign markets.

The European Union illustrates the interaction between environmental requirements and regulatory influence. Its Ecodesign for Sustainable Products Regulation establishes a framework for product sustainability requirements and digital product passports (European Parliament & Council of the European Union, 2024b). As product-specific measures become applicable, businesses supplying the European market must adjust relevant production and information management practices.

The importance of these instruments extends beyond regulatory compliance. Product information influences repair, reuse, material recovery, and the commercial circulation of secondary resources. Digital

traceability consequently becomes part of the infrastructure through which circular value chains operate.

Control over technical requirements also carries economic significance. Producers with established certification systems and digital capabilities may be better positioned to accommodate these requirements than firms lacking comparable resources. The capacity to comply with product standards increasingly affects market participation and industrial competitiveness.

This relationship brings circular economy governance into the discussion of smart power. Armitage and Nye (2007) describe smart power through the strategic combination of different sources of influence. In the circular economy context, regulatory authority, technological capabilities, market access, and institutional cooperation provide relevant channels through which economic influence is exercised.

The European experience demonstrates the importance of market size in this relationship. Firms operating across borders have commercial incentives to accommodate standards required by major destination markets. Domestic regulation thereby acquires an international economic reach.

Regulatory convergence, however, should not be mistaken for an equal distribution of adjustment costs. Compliance with digital information requirements demands investment in technical systems, data management, and verification. For firms operating with limited technical and institutional resources, these requirements may create additional adjustment challenges.

The uneven distribution of regulatory compliance costs introduces an additional dimension to the political economy of circularity. Although sustainability requirements apply to products entering the same market, firms differ considerably in their capacity to meet the associated digital and administrative obligations. These differences affect market access and competitive conditions, particularly for smaller producers and firms operating in less digitally developed economies. Regulatory interoperability and technical cooperation are therefore important for limiting unnecessary trade costs without compromising environmental standards. The economic influence associated with setting product standards remains significant, but its implications for international trade depend partly on how compliance requirements are designed and implemented.

4. Friend-Shoring, Near-Shoring and the Changing Geography of Trade

The reconsideration of global supply chains reflects growing concerns over production concentration and geopolitical exposure. Friend-shoring and near-shoring have entered industrial policy as distinct responses to these vulnerabilities. Their relevance to circularity lies in the changing geography of material recovery, processing, and manufacturing.

The economic rationale differs between the two approaches. Friend-shoring assigns importance to political alignment among trading partners. Near-shoring places greater weight on geographical proximity. Neither criterion establishes the productive efficiency or reliability of a supply relationship.

The United States–Japan Critical Minerals Agreement illustrates the incorporation of material security into strategic trade cooperation. Alongside provisions concerning critical mineral supply chains, the agreement recognizes resource efficiency and circular economy approaches (Office of the United States Trade Representative, 2023). It provides an institutional basis for cooperation between established partners, although its existence should not be interpreted as evidence of improved supply-chain performance.

Circularity complicates the economic logic of trade regionalization. Recoverable materials originate in production and consumption systems distributed across countries. Their subsequent use depends on collection networks, specialized processing facilities, and industrial demand. Restricting these flows according to political alignment can reduce access to commercially viable recovery options.

There is also a broader cost associated with supply-chain fragmentation. Cerdeiro et al. (2024), using macroeconomic simulations of large-scale trade fragmentation, estimate substantial long-term output losses under reshoring and friend-shoring scenarios. Although their analysis does not specifically address circular industries, it highlights the potential opportunity costs of supply-chain security policies that constrain international specialization.

Near-shoring presents a more differentiated economic case. Repair and remanufacturing often involve reverse logistics, product inspection, and coordination with manufacturing activities. Proximity becomes valuable when it reduces transaction costs or improves

operational efficiency. For other material streams, specialized processing at greater distance remains economically preferable.

Circular value chains should consequently be organized around the characteristics of materials and productive activities. Political alignment and geographical proximity are relevant considerations, but neither should replace an assessment of cost, capacity, and supply concentration.

Trade realignment in the circular economy is therefore better understood through changes in industrial relationships than through the formation of geographically closed production systems. Access to secondary materials, processing technologies, and reliable markets increasingly determines the position of economies within these relationships.

5. Green Trade Partnerships and the Distribution of Economic Value

International resource partnerships reveal a persistent tension between supply security and industrial development. Importing economies seek stable access to strategic materials, while resource-producing economies have an interest in expanding domestic processing and manufacturing.

This tension is visible in the evolving structure of European raw-material partnerships. Cooperation with Namibia addresses sustainable raw-material value chains and renewable hydrogen. The partnership framework includes investment, infrastructure, skills, and opportunities for local value addition. The EU–Chile partnership similarly establishes cooperation on sustainable raw-material value chains (European Commission, 2022, 2023).

These arrangements are relevant because industrial cooperation enters negotiations traditionally associated with resource access. Their developmental significance nevertheless depends on the activities that follow formal agreements.

The location of value creation remains decisive. Resource exports generate income, but the processing and transformation of materials support a different set of economic activities. Technical capabilities,

specialized employment, and links with domestic manufacturing develop where higher-value operations are established.

Circularity introduces an additional dimension to this distribution. The increasing economic relevance of recovered materials creates demand for sorting, processing, remanufacturing, and related technological services. Countries without these capabilities remain dependent on external facilities, even where they generate substantial volumes of recoverable material.

The political economy concern is therefore the position occupied within the value chain, rather than participation in circular trade alone.

For resource-producing economies, partnerships that support processing technologies, workforce development, and domestic industrial linkages offer a stronger basis for economic diversification. For importing economies, cooperation that strengthens partner capabilities broadens the available industrial supply base.

Such arrangements require more than general commitments to sustainability. Their economic content should be reflected in investment structures, technology access, industrial infrastructure, and opportunities for local firms.

The emergence of standards-based networks, resource partnerships, and regional circular production systems does not amount to a unified division of global trade into competing green blocs. Countries maintain overlapping relationships across extraction, processing, manufacturing, and technological development.

Nevertheless, the terms of participation are changing. Economies able to influence product standards and control advanced processing technologies occupy a different position from those supplying unprocessed materials or adapting to externally defined requirements.

This is the distributional question at the center of global circular economy governance.

6. Green Macroeconomics: Material Dependence, External Shocks and Economic Resilience

The macroeconomic relevance of circularity is most apparent in economies exposed to imported material costs. Commodity price

movements affect domestic production through intermediate inputs, while supply disruptions constrain output and influence investment. The intensity of these effects depends on import concentration, the availability of substitutes, and the structure of industrial demand.

Circular production changes these relationships by expanding the use of recovered resources. Its economic contribution, however, cannot be inferred from recycling activity alone. What matters is the extent to which secondary materials replace vulnerable inputs at costs compatible with productive efficiency.

The implications for external balances are particularly important. Reducing imported primary-material requirements improves the trade balance through the import-substitution channel, other factors held constant. Yet investment in circular production often requires capital equipment, technology, and energy sourced internationally. The net external effect depends on the relationship between these additional imports, displaced material purchases, and changes in export performance.

Circularity also changes the transmission of external cost shocks. Alternative sources of industrial inputs reduce exposure to specific suppliers. They do not remove the influence of global energy prices, exchange rates, or international demand on secondary-material markets.

The macroeconomic objective should therefore be defined carefully. Lower material import dependence represents a change in the structure of exposure. Greater resilience requires that this change translates into improved capacity to absorb disruptions without severe losses in output, investment, or price stability.

Strategic autonomy introduces a further distinction. An economy may recover a larger share of its material requirements domestically while remaining dependent on imported technologies or specialized processing services. Domestic resource availability and control over productive capabilities are separate dimensions of economic dependence.

Industrial policy must account for both. Investment in recycling infrastructure is economically justified where it addresses identifiable supply vulnerabilities or productive inefficiencies. Subsidizing capacity without regard to demand, technology, and operating costs transfers resources into activities whose strategic contribution remains uncertain.

The same reasoning applies to international trade cooperation. Diversification reduces concentration risk when alternative suppliers and processing networks are genuinely independent. Replacing dependence on one concentrated network with dependence on another does not establish greater resilience.

Policy evaluation should follow the economic mechanisms through which circularity operates. Material productivity, import concentration, the effective substitution of primary inputs, and sensitivity to external cost shocks offer a more meaningful assessment than operational indicators considered in isolation.

This perspective also places fiscal discipline within green industrial policy. Public investment and incentives should be evaluated against their contribution to productive capabilities, supply reliability, and resource efficiency. Environmental benefits remain essential, but they do not remove the need to assess economic additionality and long-term public costs.

7. Policy Directions

An integrated approach to circular economy policy requires coordination across industrial planning, trade governance, and macroeconomic risk management.

National strategies should identify sector-specific dependencies before prioritising investment. The relevant considerations include material criticality, technological substitutability, supply concentration, and industrial demand. This approach directs policy towards vulnerabilities that materially affect production.

Public support for circular infrastructure should be linked to processing efficiency and the capacity to supply domestic industry. Where international or regional arrangements provide reliable and competitive alternatives, cooperation deserves consideration alongside domestic capacity expansion.

Trade partnerships should also be assessed through their contribution to productive development. Investment in processing, technology transfer, industrial skills, and local value creation provides a substantive basis for cooperation between resource-producing and importing economies.

Finally, circular economy regulation requires compatible digital and technical systems. Interoperability supports the circulation of secondary materials across borders and reduces unnecessary compliance costs. The development of common standards should be accompanied by technical support for economies and firms facing substantial implementation constraints.

These priorities place circularity within an economic policy framework concerned with resource security, industrial efficiency, and the distribution of value across international production networks.

8. Conclusions

Circular economy policies are changing the economic relationships through which materials are supplied, processed, and traded. National efforts to improve resource security increasingly intersect with international product standards, industrial partnerships, and the reorganisation of supply chains.

The experiences examined in this chapter demonstrate the different policy interests shaping this transition. The Netherlands has integrated circularity into long-term resource planning. The European Union has connected material recovery with strategic industrial capacity and product regulation. International critical mineral partnerships reflect the growing importance of cooperation over processing capabilities and technological development.

These developments reveal a tension within contemporary green industrial policy. Governments seek greater control over strategic inputs while remaining dependent on international technologies, markets, and productive specialization. Friend-shoring and near-shoring reorganize these relationships, but their economic value cannot be established through political alignment or geographical proximity alone.

The distribution of industrial capabilities will remain central to the changing structure of green trade. Economies that develop processing technologies, material recovery systems, and regulatory expertise gain greater influence over the conditions of market participation. Those confined to primary-resource supply or low-value recovery activities remain exposed to established forms of dependence.

Circularity consequently provides no automatic route to strategic autonomy. Its contribution depends on whether national policies expand productive options and reduce vulnerabilities that constrain economic adjustment.

For green macroeconomic governance, this requires a more selective approach to industrial intervention and a more substantive understanding of international cooperation. Domestic capabilities should be strengthened where they improve material productivity and supply reliability. Trade relationships should remain sufficiently diversified to preserve access to specialized technologies and competitive inputs.

The political economy of circularity is ultimately concerned with the distribution of productive capabilities, economic risks, and industrial value. A successful transition requires national resource strategies that address these relationships without sacrificing the benefits of international economic integration.

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FROM ENERGY-EFFICIENT PRODUCTS TO ENERGY-EFFICIENT FACTORIES: CIRCULAR AND ENERGY EFFICIENCY PRACTICES IN THE INDUSTRIAL VENTILATION SECTOR

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Improving industrial energy efficiency remains a key priority of the green transition. According to the International Energy Agency (IEA), industry accounted for almost 40% of global final energy consumption in 2024 and has contributed approximately two-thirds of the growth in global energy demand since 2019 (International Energy Agency, 2025). Meanwhile, the average annual rate of improvement in industrial energy intensity has slowed to less than 0.5% since 2019, indicating substantial untapped potential for technological modernisation. In 2025, the IEA explicitly identified improvements in the efficiency of electric motors, fans, pumps and compressors, together with wider deployment of variable-speed drives, as priority measures.

The importance of this area is reinforced by new European Union requirements. From 24 July 2026, updated ecodesign requirements apply in the EU to industrial fans with power ratings ranging from 125 W to 500 kW1 (European Commission, 2026). The European Commission estimates that these requirements will reduce electricity consumption by fans in 2030 by approximately 31 TWh compared with a scenario without regulation. The new rules also cover part-load operation, spare parts availability and equipment repairability.

In this context, the experience of the German company ebm-papst is instructive, as it combines the production of energy-efficient ventilation technologies with their application at its own facilities. The company has stated its commitment to improving the energy efficiency of production, expanding photovoltaic generation and reducing Scope 1

and 2 emissions, and its targets for 2030 have been validated by the Science Based Targets initiative (ebm-papst, 2024). The company's successful practices in upgrading internal ventilation systems, optimising production processes, using renewable energy and implementing energy management in accordance with ISO 50001 provide a basis for examining their applicability in other sectors.

This study aims to determine how manufacturers of energy-efficient technologies can use their own production facilities as demonstration sites for the green transition and to substantiate policy instruments capable of encouraging wider adoption of this approach. To achieve this aim, the study sets out to analyse the role of energy-efficient technologies in modernising industrial systems; examine ebm-papst's implementation of its own technological solutions at its production sites in Germany and China; identify the features of this practice that make it a potential model for the green and circular transition; formulate practical recommendations for national and sectoral policies; and assess the potential for transferring this approach to other enterprises, sectors and geographical contexts.

Industrial ventilation systems account for a substantial share of energy consumption in production infrastructure. According to the Ecodesign Impact Accounting Overview Report 2024, fans with power ratings ranging from 125 W to 500 kW represent approximately 5% of all fans used in the EU but account for around 80% of the electricity consumed by fans (Wierda & Zanuttini, 2024). In 2010, their electricity consumption amounted to 230 TWh per year. Significant energy savings can be achieved not only by increasing the efficiency of the fan itself but also by optimising electric motors, drives and control systems. The International Energy Agency identifies the modernisation of electric motors and fans, the use of variable-speed drives and digital monitoring as key measures for improving industrial energy efficiency.

Figure 1 illustrates the effects of regulatory and technological changes. Under the scenario without measures, electricity consumption by industrial fans in the EU was projected to rise to 300 TWh in 2020 and 345 TWh in 2030. Under the scenario with ecodesign measures, the corresponding figures are 281 and 294 TWh, implying approximately 15% lower consumption in 2030 (Wierda & Zanuttini, 2024). Improvements in axial fans account for approximately half of the projected savings, while backward-curved centrifugal fans account for a

further 37%. The updated EU ecodesign requirements for industrial fans, applicable from July 2026, further strengthen a systems approach to energy efficiency by addressing operation under different load conditions, repairability and spare parts availability (European Commission, 2026).

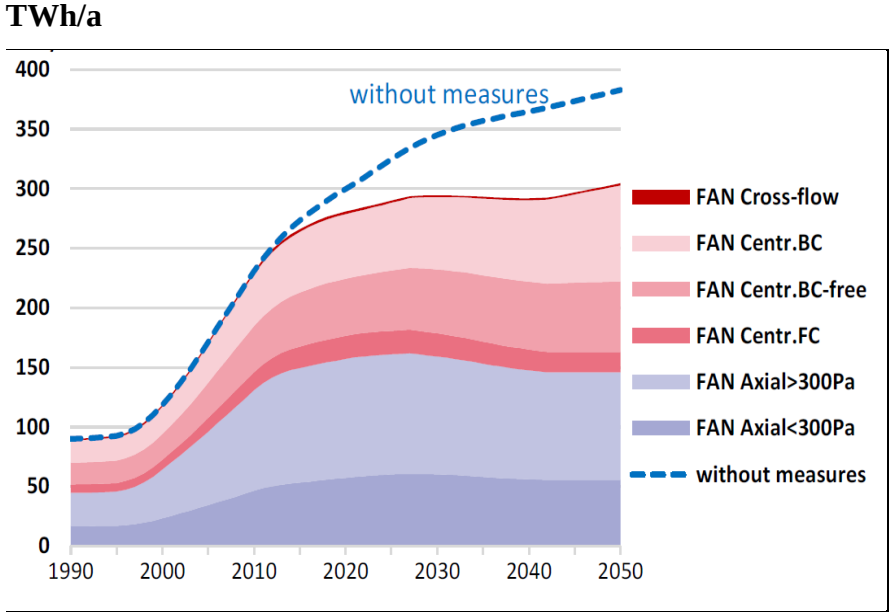


Figure 1. Annual electricity consumption by industrial fans in the EU-27 under scenarios with and without regulatory measures, 1990–2050.

Source: Wierda and Zanuttini (2024, p. 103).

These data indicate that industrial ventilation provides an informative context for studying the green and circular transition: high energy consumption is accompanied by already measurable effects of technological modernisation and regulation. At the same time, improving repairability, upgrading existing systems, increasing component efficiency and extending component service life provide practical opportunities to implement circular economy principles. The experience of companies that both manufacture energy-efficient equipment and deploy it in their own production systems is therefore particularly valuable for further analysis.

The experience of ebm-papst is instructive for analysing the transition from manufacturing energy-efficient equipment to establishing an energy-efficient production system. The company states that it pursues a comprehensive approach to sustainability encompassing product energy efficiency, responsible resource use, digitalisation and emissions reduction. At the corporate level, ebm-papst identifies energy consumption and emissions as key environmental priorities and expresses its commitment to developing energy-efficient, durable solutions suitable for reuse or recycling in accordance with circular economy principles. One practical manifestation of this approach is the modernisation of its own ventilation infrastructure. According to the company, replacing equipment in its internal ventilation systems with a new generation of ebm-papst fans achieved energy savings of approximately 10%. The company thus acts both as a supplier of energy-efficient technologies to external customers and as a user of these solutions at its own facilities (ebm-papst, n.d.).

The production site in Hollenbach, Germany, provides an illustrative example. According to the company's official website, the site's three photovoltaic installations jointly generate approximately 5.7 million kWh of electricity annually, compared with the facility's total demand of around 10 million kWh. On-site generation can therefore potentially cover more than half of the site's energy requirements. In addition, the company's Sustainability Report describes the use of waste heat from production processes and the data centre to heat warehouse and production spaces, as well as measures to introduce LED lighting and progressively electrify heat supply (ebm-papst, 2024).

A second important example is the plant in Xi’an, China. In 2025, ebm-papst described this facility as a demonstration project for responsible industrial construction. The plant incorporates energy-efficient glazing, LED lighting, a ground-source heat pump and a large-scale photovoltaic system (ebm-papst, 2025). The company also reports the use of reusable packaging and a fully electric employee shuttle bus fleet. In January 2025, the plant was awarded National Green Factory status by China's Ministry of Industry and Information Technology (ebm-papst, 2025).

A comparison of the successful Hollenbach and Xi’an plant cases shows that ebm-papst's approach extends beyond the introduction of a single type of energy-efficient equipment. It combines ventilation

upgrades, on-site renewable energy generation, waste heat recovery, energy-efficient lighting and energy management. This integration allows the company's facilities to serve as demonstration sites for testing and disseminating technological solutions for the green transition.

The ebm-papst case can be regarded as an example of best practice primarily because it combines technological, operational and resource efficiency. First, the company applies its own energy-efficient solutions at its production sites. This enables the manufacturer both to offer its technology to the market and to verify its effectiveness in its own operations. Second, modernisation is systemic: it combines improvements in ventilation efficiency, renewable energy use, energy management in accordance with ISO 50001 and the optimisation of production processes. In the 2023/24 financial year, ebm-papst's global energy consumption decreased from 155,727 to 141,066 MWh [5]. Third, the company's approach is consistent with circular economy principles. Upgrading existing equipment can improve its efficiency without replacing the entire system, while the use of compatible new components can potentially extend the service life of existing infrastructure. The company itself states its commitment to resource efficiency, product recyclability and a cradle-to-cradle approach. Fourth, the outcomes of this approach can be quantified through indicators of energy consumption, on-site generation and emissions. Moreover, successful practices have been implemented at more than one site, suggesting that the model can be adapted to different production and geographical contexts. The value of the ebm-papst case for energy efficiency policy development therefore lies in demonstrating that the circular and green transition in industry can be achieved through the systematic upgrading of existing production infrastructure rather than through a single technology.

An examination of ebm-papst's experience suggests that energy efficiency policy can be substantially more effective when it supports the modernisation of the production system as a whole rather than individual technologies. In this context, it is important to identify measures that can encourage companies and governments to move in this direction.

In our view, financial support for upgrading industrial ventilation systems should be expanded. Such support could include grants, concessional loans, tax incentives and partial reimbursement of investment costs incurred in replacing obsolete fans, motors and control systems. However, modernisation should not be confined to complete

equipment replacement. Where an existing system can be upgraded by replacing individual components or modernising drives or automation systems, dedicated support should be provided for this approach. It can extend the service life of infrastructure and reduce material costs.

A second important priority, in our view, is to focus on the results achieved rather than merely on the purchase of new equipment. Projects receiving public support should therefore include measurements of energy consumption before and after modernisation, actual energy savings and, where possible, emissions reductions. These indicators should be central to the assessment of project outcomes.

A third priority is to promote a model of energy efficiency in which manufacturers apply their own technologies at their own facilities. These production sites can become demonstration centres where other companies can observe actual implementation results rather than a promotional concept.

Green projects should be grounded in systems thinking and a comprehensive approach: ventilation upgrades, digital monitoring, heat recovery, local renewable energy generation and energy management should be treated as interconnected elements of a single system. This approach may be useful well beyond the ventilation sector and can be extended to machinery manufacturing, the food and pharmaceutical industries, logistics and warehousing. For Ukraine, it is particularly relevant in the context of future industrial reconstruction, which offers an opportunity to incorporate energy-efficient and circular solutions from the outset rather than simply restore existing systems.

In conclusion, industrial energy efficiency has long extended beyond the performance characteristics of an individual fan, motor or other item of equipment. Substantial benefits emerge when an enterprise operates as an integrated system by modernising equipment, managing energy consumption and using digital monitoring, heat recovery and on-site energy generation. The ebm-papst case illustrates this transition from a manufacturer of energy-efficient products to a company seeking to implement the same principles at its own factories. This is the principal value of the practice examined in this article: technology becomes an integral part of the enterprise's operating model rather than remaining solely a marketable product. Under this approach, modernising an individual process—in this case, the ventilation system—forms part of a broader model of low-carbon and circular production. Of particular

importance is the ability of manufacturers to turn their own facilities into demonstration sites for their solutions, thereby reducing scepticism towards new technologies. This leads to the conclusion that public policy should support systemic modernisation with measurable outcomes, including actual energy savings, emissions reductions and a longer life cycle for production infrastructure, rather than simply incentivising the purchase of more efficient equipment.

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FINANCING CIRCULAR ECONOMY FOR SMES IN INDONESIA: GREEN FINANCE, ESG INTEGRATION, AND POLICY TRANSFERABILITY

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Abstract

Indonesia's circular transition depends on financing the micro, small, and medium enterprises (MSMEs) that perform most value-retention activities, yet MSMEs held only about 16.7% of formal financing in mid-2026. We argue that the binding constraint is a misalignment between how circular value is created and how credit and climate risk are measured. Drawing on recent Indonesian reforms, including POJK 19/2025, the TKBI taxonomy, the PSPK disclosure standards, and OJK's CRMS 2026 guidance, we propose four recommendations: a circularity-linked blended finance and guarantee facility; an ESG-Lite circularity passport interoperable with the EU VSME standard; recognition of verified circularity in taxonomy and climate-risk frameworks; and university circular economy hubs. Transferability to ASEAN, Rwanda, and Europe is assessed functionally.

Keywords: *circular economy; green finance; MSMEs; ESG; climate risk; Indonesia*

1. The Policy Challenge

Indonesia's circular economy roadmap projects that circular strategies in food, electronics, plastic packaging, construction, and textiles could add up to Rp638 trillion to GDP by 2030 and create 4.4 million green jobs, yet recycling in these sectors remains around 5% (Bappenas, 2024). Globally, the share of secondary materials has fallen

to 6.9% (Circle Economy, 2025). Because circularity means retaining product and material value through reuse, repair, and remanufacturing rather than recycling alone (Kirchherr et al., 2023), much of this work is performed by small firms.

Those firms are underfinanced. MSMEs generate about 61% of GDP and 97% of employment (Coordinating Ministry for Economic Affairs, 2022), yet in June 2026 they held only 16.73% of total financing, which grew a mere 2.16% year on year (Kontan, 2026).

The literature explains why. Market barriers such as high upfront costs and cheap virgin materials reinforce cultural resistance (Kirchherr et al., 2018); SMEs cite capital shortages and administrative burden (Rizos et al., 2016); access to conventional finance still conditions adoption (Ghisetti & Montresor, 2020); and growth benefits emerge only beyond a threshold investment of 10% of revenue (Demirel & Danisman, 2019). Lenders' standard tools poorly assess models built on retained asset value and secondary-material prices (de la Cuesta-González & Morales-García, 2022), and the financing of circularity remains under-researched (Ma et al., 2025). Three frictions follow: information asymmetry, mispricing of asset-light models, and fragmented sustainability data requests.

2. A Shifting Regulatory Frontier

Climate risk has become a prudential concern since stress tests exposed financial-system vulnerability to policy-sensitive sectors (Battiston et al., 2017). The European Union pairs this with proportionality: Recommendation (EU) 2025/1710 endorses the voluntary VSME standard as the reference for SME value-chain data requests (European Commission, 2025).

Indonesia's architecture has thickened rapidly. TKBI Version 2 targets corporate and MSME users but defers waste management to Version 3 (Otoritas Jasa Keuangan [OJK], 2025a). PSPK 1 and 2, aligned with IFRS S1 and S2, take effect in January 2027 (Ikatan Akuntan Indonesia, 2025), extending data expectations to small suppliers. POJK 19/2025 requires simplified feasibility assessment, alternative credit scoring, and MSME financing plans (OJK, 2025b).

Most consequential is CRMS 2026, which expands the 2024 framework to seven books, updates emissions methods, climate scenarios, and physical-risk data, and introduces a Standardized Approach for banks

without internal models (OJK, 2026). This proportionality brings climate analytics within reach of the smaller banks serving MSMEs. Yet where borrower-level evidence is absent, standardised approaches default to sectoral proxies that may label waste, plastics, and textiles high-risk, tightening credit for the very firms reducing emissions there. Reconciling prudential rigour with circular inclusion is the central policy task.

3. Good Practice and Existing Experience

Building blocks exist. Community waste banks operate under a dedicated ministerial regulation, and Bank Indonesia's partnerships with universities to scale SIAPIK digital bookkeeping provide a precedent for academic intermediation (Bank Indonesia, 2023). Among Indonesian SMEs, organisational agility drives circular innovation (Arsawan et al., 2026), so capability must accompany capital. Digital technologies enable traceability but create information vulnerabilities (Chauhan et al., 2022), while fintech and performance-based instruments are emerging as circular finance enablers (Kumar et al., 2025). Guarantee ratios should be calibrated to lender and macroeconomic conditions (Yoshino & Taghizadeh-Hesary, 2019), green credit guarantees can raise risk-adjusted returns (Taghizadeh-Hesary & Yoshino, 2019), and credible ESG disclosure lowers SMEs' cost of capital (Gjergji et al., 2021).

4. Policy Recommendations

Recommendation 1: Circularity-linked blended finance with a calibrated partial guarantee. Concessional capital should absorb first losses and fund technical assistance, while a legally mandated guarantor covers an illustrative 50% of eligible losses so that lenders retain exposure. Eligible uses include repair and remanufacturing equipment, sorting technology, and reverse-logistics working capital, with margin step-downs tied to verified circularity indicators.

Recommendation 2: An ESG-Lite circularity passport. OJK, the Ministry of MSMEs, lenders, and universities should co-develop a one-page template mapped to the VSME Basic Module, PSPK, and TKBI, recording materials recovered and rejected, paid employment, safety, inclusion of informal collectors, and basic governance. Built on SIAPIK and accepted as a single data request, it would also feed alternative credit scoring under POJK 19/2025.

Recommendation 3: Circularity in risk frameworks. TKBI Version 3 should include repair, remanufacturing, and waste-

management criteria with a simplified MSME pathway, and banks using the CRMS 2026 Standardized Approach should be allowed to replace sectoral proxies with verified passport evidence.

Recommendation 4: University circular economy hubs. Competitive grants should fund clinics in which business faculties provide bookkeeping and passport verification while engineering partners assess material recovery, with Universitas Mercu Buana as a proposed pilot. Lenders retain credit decisions, and academic endorsement is never a repayment guarantee.

A 24-month municipal pilot with a comparison group and public reporting should precede scale-up (Table 1).

Table 1 *Policy architecture for financing circular MSMEs*

Recommendation	Lead actors	Indicative KPI
1. Blended finance and guarantee	Ministry of Finance, guarantors, banks	New circular borrowers; loss rate
2. ESG-Lite passport	OJK, Ministry of MSMEs, lenders	Passports verified
3. Circularity in risk frameworks	OJK	Circular MSME financing share
4. University hubs	Universities, Ministry of Higher Education	Tonnes verified recovered

Note. Source: Authors' synthesis.

5. Transferability

Transfer should replicate functions, not institutions. Vietnam, the Philippines, and other ASEAN economies could link enterprise agencies, universities, and lenders through local-language passports. Rwanda, whose development bank absorbed national SME guarantee services in December 2025 (KT Press, 2025), could adapt the guarantee component, subject to recycling-market depth. Community norms such as *gotong*

royong and *umuganda* can mobilise participation but cannot replace contracts. Transfer requires a legal guarantee mandate, functioning secondary-material markets, interoperable data, institutional capacity, and safeguards for informal workers.

6. Conclusion

Indonesia need not invent circular finance; it must connect existing instruments. Deliberately aligned, taxonomy, disclosure standards, MSME access rules, and CRMS 2026 can make small circular firms legible to lenders, rendering the transition both prudentially sound and socially inclusive.

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CIRCULAR ECONOMY AND DIGITAL TRANSFORMATION IN THE APPAREL INDUSTRY: A CRITICAL CASE STUDY OF PATAGONIA'S WORN WEAR PROGRAMME

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Abstract

The apparel industry faces persistent tensions between commercial growth and the environmental consequences of resource-intensive production. This chapter examines Patagonia's Worn Wear programme as a case of circular business-model development, with particular attention to repair, reuse, resale and digital service delivery. Using qualitative documentary analysis of company materials and established circular economy literature, the study evaluates how product-life extension can generate customer and business value while potentially reducing demand for new garments. The analysis finds that Worn Wear offers a coherent set of mechanisms for keeping clothing in use, supported by online repair information and a structured trade-in system. Nevertheless, restricted product eligibility, geographical concentration, logistical impacts and uncertainty over the displacement of new purchases constrain conclusions about net environmental benefits. The chapter argues that the significance of Worn Wear lies in integrating post-purchase services into the business model, while demonstrating why circularity should be assessed through measurable consumption and production outcomes rather than programme activity alone.

Keywords: circular economy; Patagonia; Worn Wear; clothing repair; resale; digitalization; sustainable business models.

1. Introduction

The conventional apparel business model relies heavily on extracting resources, manufacturing garments, selling them and eventually disposing of them. A circular economy challenges this sequence by retaining the value of products and materials through continued use, repair, redistribution and recovery. Yet circularity and sustainability are not identical: a circular activity does not automatically yield a net reduction in environmental pressure (Geissdoerfer et al., 2017). This distinction matters particularly in clothing, where shorter use periods and repeated purchases can undermine improvements in product efficiency.

Patagonia, the US outdoor apparel company founded in 1973, provides an instructive case because its Worn Wear programme explicitly promotes keeping existing garments in use. Its activities include repair advice, repair services, trade-ins and resale of eligible secondhand products (Patagonia, n.d.-a). Rather than treating a garment's first sale as the end of the customer relationship, the programme extends the company's involvement into the post-purchase phase. The central research question is: How does Patagonia's Worn Wear programme operationalize circular economy principles through repair, reuse, resale and digital services, and what limits its potential sustainability contribution?

2. Theoretical framework: extending product life

Bocken et al. (2016) distinguish strategies that slow, close and narrow resource loops. Slowing loops involves extending product lifetimes through durable design, maintenance, repair and reuse; closing loops concerns recovering materials after use; narrowing loops reduces resource use per product or activity. Worn Wear primarily illustrates slowing loops. A jacket that is repaired and worn for additional seasons can continue delivering utility without requiring immediate replacement. Resale similarly allows an existing product to serve another user.

This classification is important because resale is not synonymous with textile-to-textile recycling. A repaired or resold garment retains much of its original embedded material and manufacturing value. By contrast, recycling generally requires further processing and may involve losses of quality or material. The circular economy therefore involves more than managing waste: it also concerns the design of products,

customer incentives and business relationships that influence how long goods remain useful.

From a management perspective, a company offering repair and resale changes its value proposition. Value is generated not only through the initial sale but also through services, customer retention and the continued circulation of branded products. However, these mechanisms only support environmental objectives to the extent that they reduce virgin production or otherwise avoid impacts that would have occurred without the programme.

3. Methodology

This study adopts an exploratory, qualitative single-case design using documentary analysis. Patagonia's Worn Wear website, repair and trade-in information are treated as primary organizational documents; peer-reviewed research on circular economy business models provides the analytical framework. The author's existing presentation is used to identify the programme components to investigate, rather than as independent empirical evidence. Four themes structure the analysis: (1) product-life extension through repair; (2) redistribution through reuse and resale; (3) digital enablement of post-purchase services; and (4) environmental and managerial limitations.

The approach is interpretive rather than causal. Publicly available descriptions can establish what services are offered and how they are intended to operate, but they cannot independently verify avoided emissions, changes in total garment production or the purchasing behaviour of individual customers. Accordingly, company claims are attributed to the company and environmental benefits are described as conditional where direct impact evidence is unavailable.

4. Worn Wear as a circular business model

4.1 Repair and continued use. Worn Wear promotes the maintenance and repair of clothing as alternatives to replacement. Patagonia makes repair guidance available online and provides routes to professional assistance. Repair can involve patches, stitching or the replacement of components such as zippers and buttons. These activities preserve an item's functional value and potentially delay the need for a new purchase. Their effectiveness, however, depends on garment condition, repairability, customer willingness and whether the item remains in active use (Patagonia, n.d.-a).

4.2 Reuse and resale. Patagonia's trade-in process accepts selected clean, functional used garments and equipment. Eligible items are assessed and exchanged for merchandise credit, while qualifying used products are offered for resale. The process makes secondhand clothing part of an organized retail channel rather than leaving redistribution entirely to informal markets. It also offers the company a continuing relationship with customers after the initial purchase (Patagonia, n.d.-b). Importantly, the credit may be used for new products as well as used ones. Thus, a trade-in is not itself proof that the customer has reduced purchases of newly manufactured clothing.

4.3 Digitalization and customer access. Digital tools connect the physical activities of repair and redistribution. Online repair guides and videos enable customers to attempt some repairs themselves, while digital trade-in information and service requests reduce the informational effort required to participate. In this sense, digitalization is an enabling infrastructure rather than the environmental outcome itself. Its managerial value lies in making circular services easier to discover, understand and use. This does not establish that Worn Wear employs a digital product passport or comprehensive product-level tracking system; such claims would require separate evidence.

4.4 Strategic value. The programme may strengthen brand relationships by reinforcing expectations of durability and after-sales support. It also creates a resale channel for previously sold products. The strategic innovation is the expansion of the business model beyond one-off transactions: a product can remain commercially and relationally relevant after its first owner. At the same time, any resulting customer loyalty or revenue growth should not be confused with verified environmental gains.

5. Critical discussion

Worn Wear offers a practical example of circular business-model strategies, but four limitations qualify its interpretation. First, resale is selective: Patagonia requires products to meet specified condition and category criteria. Items that are heavily damaged or excluded from the programme cannot necessarily circulate through its resale channel (Patagonia, n.d.-a). Second, the company states that its buyback and used-gear sales programme is limited to the United States. This geographic concentration restricts access and complicates the transferability of the model to other markets.

Third, repair and resale still require resources, including labour, transport, packaging and digital infrastructure. Their net environmental effects must be compared with plausible alternatives. The relevant question is not simply how many garments are repaired or resold, but whether these activities replace production and purchase of new garments. If customers buy secondhand clothing in addition to, rather than instead of, new products, the reduction in resource demand may be smaller than the number of resale transactions suggests.

Fourth, Worn Wear operates alongside Patagonia's continued production and sale of new garments. This creates a managerial tension between encouraging longer use and maintaining commercial growth. A credible assessment of circular performance would therefore examine the share of company activity represented by repair and resale, the additional years of garment use achieved, the extent of new-product displacement and the overall trajectory of material throughput. Without such indicators, the evidence supports the existence of circular practices, but not a claim that the entire business is fully circular.

The case suggests a broader lesson for international business: circularity is partly a problem of incentives and service design. Product quality, convenient repair access, trusted secondhand markets and customer communication must work together. Digitalization can reduce participation barriers, but it cannot by itself overcome geographical restrictions, unsuitable product designs or consumption patterns that favour constant replacement.

6. Conclusion

Patagonia's Worn Wear programme illustrates how an apparel company can operationalize circular economy principles through repair, reuse and resale, supported by digital information and service channels. Its strongest contribution is the redefinition of the post-purchase relationship: the garment is treated as an asset whose value can be preserved beyond the first transaction. Yet the programme's environmental effectiveness remains conditional on actual product-life extension and displacement of new production. Future research should combine customer-level purchasing data with life-cycle assessment and longitudinal measures of product use. For managers, Worn Wear demonstrates both the promise of circular service innovation and the need to evaluate outcomes rather than intentions.

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CIRCULAR ECONOMY AND GREEN INNOVATION IN THE SPORTSWEAR INDUSTRY: A CRITICAL CASE STUDY OF THE ADIDAS–PARLEY PARTNERSHIP

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Abstract

This chapter examines the partnership between Adidas and Parley for the Oceans as a case of green innovation in the sportswear industry, assessing it against the principles of the circular economy. Beginning with a 2015 prototype and scaling to millions of pairs, the collaboration turned intercepted coastal plastic into performance yarn and became one of the most visible sustainability initiatives in the sector. Drawing on company statements, media investigations and regulatory complaints, the chapter argues that the partnership was an important material and communication innovation but fell short of a genuinely circular system. Upcycling marine plastic diverts waste without closing the loop, microplastic shedding and high production volumes remain unresolved, and questions about supply-chain traceability weakened the credibility of the claims. The later end of the partnership and the more circular but marginal Futurecraft.Loop project reinforce this assessment. The chapter concludes that credible green innovation requires traceable materials, design for recovery and business models that reduce, rather than merely re-source, plastic use (Hailemariam & Erdiaw-Kwasi, 2022).

Keywords: circular economy; green innovation; sportswear; Adidas; Parley for the Oceans; greenwashing; upcycling.

1. Introduction

Modern sportswear is predominantly composed of synthetic polymers. Athletic footwear, jerseys, and activewear frequently utilize polyester—a synthetic fiber derived from crude oil. Given the short lifecycle of these products, the vast majority are discarded as solid waste, while routine laundering continually releases microplastics into marine ecosystems (Dew et al.,2026). In contrast, the circular economy proposes a regenerative framework. Replacing the conventional linear model of "extract, produce, discard," it seeks to extend product lifespans through systematic reuse, repair, and recycling. Numerous apparel brands have increasingly aligned themselves with circular principles (Hailemariam & Erdiaw-Kwasi, 2022). Among the most prominent implementations was the decade-long collaboration between Adidas and Parley for the Oceans, which converted intercepted marine plastic debris into yarn for footwear and apparel. Although the project garnered widespread acclaim and commercial success, its conclusion sparked intense critique regarding unsubstantiated environmental claims. Existing literature largely splits into two extremes: praising the initiative as a landmark solution or dismissing it as mere greenwashing. A critical gap remains in evaluating the case against strict circular economy metrics. This chapter addresses this oversight, contending that while the Adidas–Parley venture was an influential innovation and awareness campaign, it did not constitute a closed-loop circular system. Through a detailed analysis of its strengths and systemic shortcomings. This chapter derives practical implications for sustainable industry practices and regulatory policy.

2. Case Background

The collaboration between Adidas and Parley for the Oceans began as a high-profile pilot before expanding into a large-scale commercial operation. The partnership was publicly unveiled at a United Nations General Assembly event in 2015 with the presentation of a prototype shoe. This initial reveal was followed by a limited production run of 50 pairs in 2016 to test feasibility and raise public awareness.

Following this pilot stage, the initiative scaled rapidly:

> **2017:** Adidas sold over one million pairs of shoes incorporating Parley Ocean Plastic, with each pair averaging the equivalent of 11 recycled plastic bottles.

2021: Total production reached over 30 million pairs made with ocean-bound plastic since the start of the partnership, with approximately half of those produced in 2020 alone.

Parley Ocean Plastic refers to plastic waste intercepted on remote islands, beaches, and in coastal communities before it can enter the ocean, which is then processed and upcycled into high-performance technical yarn. To complement material innovation with consumer engagement, the partnership launched the participatory **"Run for the Oceans"** campaign. Through the Adidas digital fitness application, distance logged by global participants was translated into corporate financial contributions to fund Parley's global marine clean-up network and educational programs.

3. Theoretical Framework: Circular Economy and Sustainable Business Models

(Bocken et al., 2016) identify strategies for slowing, closing, and narrowing resource loops:

Slowing resource loops: Extends product lifetimes through design for durability and repair.

Closing loops: Returns materials to productive use through recycling and material recovery.

Narrowing loops: Reduces the raw resource input required per product or service.

The Adidas–Parley partnership primarily illustrates the **closing of resource loops** through the recovery and reuse of plastic waste as a substitute for virgin polyester in selected product lines.

From a business perspective, this approach links environmental objectives with product development, material sourcing, and brand positioning. Collaboration allows companies to access external expertise and develop alternative materials, while environmental organizations contribute knowledge, awareness, and global networks. Nevertheless, circular economy strategies must be evaluated according to their actual environmental and resource outcomes rather than their stated intentions alone (Geissdoerfe, 2016).

4. Critical Discussion and Analysis

While the Adidas–Parley partnership was widely celebrated as a benchmark for corporate environmental responsibility, evaluating the

initiative against circular economy frameworks reveals critical structural and operational limitations. This section analyzes the partnership across four key dimensions: material upcycling versus closed-loop design, microplastic pollution, supply-chain traceability, and the marginalization of true circular experiments like Futurecraft.Loop.

4.1 Upcycling vs. True Circularity: Downstream Waste Interception

From a circular business model perspective (Bocken et al., 2016). The Parley collaboration operates primarily as an **upcycling mechanism** rather than a closed-loop product system. By collecting ocean-bound polyethylenterephthalat (PET) bottles and converting them into footwear yarn, the partnership successfully diverts post-consumer waste from marine ecosystems.

However, substituting virgin polyester with ocean-bound plastic does not inherently close the material loop of the footwear itself:

Linear End-of-Life: Sportswear made from upcycled PET bottles is rarely recycled again after consumer use due to material blending, technical composite construction, and adhesives.

Open-Loop Cascade: Transforming a recyclable PET bottle into an unrecyclable composite shoe cascades the material down a path toward eventual incineration or landfill disposal, effectively postponing waste rather than preventing it.

4.2 The Persistent Challenge of Microplastic Shedding

A significant environmental limitation of synthetic textiles—whether derived from virgin petroleum or recycled ocean plastic—is the release of synthetic microfibres during production, wear, and laundering (Dew et al., 2026).

Physical Degradation: Recycled polyester yarns, when processed into athletic apparel and shoe uppers, continue to shed microplastics through mechanical friction and washing.

Ecosystem Impact: These microplastics enter municipal waterways and aquatic food chains. Consequently, while the partnership intercepts macro-plastic waste from beaches, the end-products risk contributing to micro-plastic pollution throughout their active lifecycle, highlighting an unaddressed ecological trade-off in recycled synthetic footwear.

4.3 Supply-Chain Traceability and Credibility Risks

As consumer and regulatory scrutiny surrounding "greenwashing" intensified, questions regarding supply-chain verification weakened the perceived credibility of ocean-plastic claims:

Verification Challenges: Distinguishing ocean-bound plastic intercepted near shorelines from standard post-consumer recycled PET requires rigorous third-party auditing and unbroken chain-of-custody tracking.

Corporate Disclosure Gaps: Independent environmental investigations and regulatory complaints pointed out that generic claims of "recycled ocean plastic" often lacked granular batch-level transparency.

Aggregate Reporting vs. Specific Claims: As Adidas reported that 99% of its overall polyester portfolio was recycled by 2023 , distinguishing between low-cost recycled PET bottles and true Parley Ocean Plastic became increasingly difficult for external stakeholders to verify, raising concerns about brand-driven narrative amplification over measurable impact.

4.4 Why Futurecraft.Loop Remained Marginal

In contrast to the open-loop Parley initiative, Adidas's **Futurecraft.Loop** project presented a genuinely circular model—utilizing a single polymer (thermoplastic polyurethane) without adhesives, explicitly designed to be returned, remelted, and remade into new technical shoes.

Despite its conceptual alignment with closed-loop principles, Futurecraft.Loop remained a limited, experimental project for several economic and structural reasons:

1. **Reverse Logistics Costs:** Scaling a circular shoe requires expensive, globally coordinated take-back infrastructure, sorting systems, and specialized chemical processing.
2. **Consumer Behaviour Barriers:** A closed-loop system depends on high consumer return rates, which linear retail markets are currently ill-equipped to enforce or incentivize.
3. **Commercial Scalability:** Upcycling PET bottles via the Parley model allowed Adidas to seamlessly leverage

existing linear manufacturing and supply-chain infrastructure while capitalizing on strong marketing narratives. Conversely, Futurecraft.Loop required fundamental business model reconfiguration, leading the company to prioritize the marketing-friendly upcycling model over full circularity.

5. Conclusion

Looking back at the ten-year teamwork between Adidas and Parley for the Oceans, I realize this project made a big difference.It proved that we can take recycled trash and make stylish, top-quality sportswear that people love. This showed that large companies and environmental groups can team up, and it helped millions of people understand the big problem of plastic waste in our oceans. But when I think about this project in the way a real circular economy works, I notice big shortcomings. Although the partnership was successful in terms of branding and waste clean-up, it was not a closed-loop system. Picking up plastic from beaches is good, but when that plastic is made into shoes, those shoes can't be recycled once they are used up. Even after washing, they still release microplastics, and Adidas kept making millions of products using their usual, large-scale production methods. Besides that, it was tough for people outside the group to check exactly where all the plastic was coming from. It's also interesting to note that Adidas's most genuine circular project, the Futurecraft.Loop shoe, designed to be melted down and made into something new, stayed a small experiment, while the Parley line became more prominent. In my opinion, the key message for the sportswear industry is clear: true green innovation goes beyond just finding new ways to reuse plastic. If companies really want to be sustainable, they need to have clear and open supply chains, create products that can be completely recycled, and run their businesses in a way that uses less plastic overall—not just recycling the plastic into new items.

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