SEESDGJ
Social, Ecology, Economy for Sustainable Development Goals Journal
SEESDGJ 3(1): 33–56
ISSN 3025-3942

An ecosystem approach to circular economy implementation and efficiency in Indonesia: A global comparative analysis

Kevin Ibrahim Suryo[1*]
[1] *School of Environmental Science, Universitas Indonesia, Jakarta, 10430, Indonesia.*
*Correspondent: kevin.ibrahim@ui.ac.id

Received Date: May 23, 2025 Revised Date: July 24, 2025 Accepted Date: July 31, 2025

ABSTRACT

Background: This study examines Indonesia's adoption of circular-economy (CE) principles through an ecosystem lens and benchmarks national progress against leading global models. **Method:** Drawing on a review of academic articles, policy reports, and case studies, nine Indonesian initiatives are cataloged, ranging from Mycotech Lab's biowaste valorization to PT Pertamina's circular-carbon programs and community-driven collaborations like LTKL. **Findings:** These examples demonstrate localized successes in waste reduction, resource recirculation, and stakeholder engagement, yet they remain largely sector-specific and pilot-scale. In contrast, regions such as the European Union, China, and Finland operate under comprehensive, economy-wide frameworks with binding targets, dedicated financing mechanisms, and mandatory extended-producer-responsibility schemes. Quantitative metrics from Indonesian projects show material savings (e.g., 2,200 tons of plastic avoided by BulkSource) and emission reductions (e.g., 352,000 ton CO_2eq cut by Pertamina). Meanwhile, qualitative analysis highlights enabling factors, including multi-stakeholder collaboration and eco-innovation; as well as persistent barriers such as policy fragmentation, limited funding, and uneven data availability. A cross-case synthesis shows the absence of harmonized indicators and national coordination, which hinders scaling and aggregation of sectoral gains into systemic impact. **Conclusion:** It is concluded that Indonesia's transition to a mature CE requires the establishment of a coherent national roadmap with clear targets, robust monitoring, and inclusive governance structures that integrate informal and rural actors. Strengthening financial instruments, such as green bonds and blended-finance vehicles, and embedding circular criteria in public procurement will be critical to mobilizing investment and promoting widespread adoption. By aligning policy, finance, and community engagement, progress toward systemic circularity can be accelerated. **Novelty/Originality of this Article:** This study uniquely integrates ecosystem-based evaluation with quantitative and policy-level benchmarking to propose a strategic roadmap for Indonesia's systemic CE transition.

KEYWORDS: circular economy; ecosystem approach; Indonesia; global comparative analysis.

1. Introduction

The concept of the circular economy (CE) becomes a critical approach to addressing global sustainability challenges, particularly by shifting from linear resource consumption to more regenerative systems (Alka et al., 2024). Within this context, a circular ecosystem can be described as a regenerative economic model that retains the highest possible utility and value of products, components, and materials throughout their life cycles. According to the Ellen MacArthur Foundation (2015), this system is designed to be restorative and regenerative by distinguishing between technical and biological cycles, thereby decoupling economic growth from finite resource consumption (Ellen MacArthur Foundation, 2015).

Cite This Article:
Suryo, K. I. (2025). An ecosystem approach to circular economy implementation and efficiency in Indonesia: A global comparative analysis. *Social, Ecology, Economy for Sustainable Development Goals Journal. 3*(1), 33-56. https://doi.org/10.61511/seesdgj.v3i1.2025.1887

This approach does not simply replace the traditional “end-of-life” mindset with recycling. Rather, it actively manages resource input, procurement, production, and reprocessing in a way that maximizes overall ecosystem functioning and human well-being (Murray et al., 2017). Furthermore, the circular ecosystem emphasizes closed-loop material flows that internalize the environmental externalities of virgin resource extraction and waste generation (Sauvé et al., 2016). This approach emphasizes the importance of strategic design through maintenance, repair, reuse, remanufacturing, refurbishing, and recycling to slow, close, and narrow material and energy loops (Geissdoerfer et al., 2017). In doing so, it minimizes waste, emissions, and energy leakage while implementing a system that is not only sustainable but also economically beneficial. Kirchherr et al. (2017) and Korhonen et al. (2018) further suggest that these ecosystems promote job creation, reduce carbon emissions, and stimulate economic growth by utilizing renewable resources and innovative recycling practices (Kirchherr et al., 2017; Korhonen, Nuur, et al., 2018) .

The operational principles in CE consist of two target principles and three core principles (Suárez-Eiroa et al., 2019). The first target operational principle focuses on adjusting inputs to the system to align with natural regeneration rates by minimizing non-renewable resource use and promoting eco-efficiency, renewable energy, and dematerialization (Elia et al., 2017). The second target principle emphasizes adjusting outputs from the system to conform to the biosphere’s absorption capacities, thereby reducing technological waste and emissions (Elia et al., 2017). The core operational principles include closing the system through effective waste management and recycling, maintaining resource value by enhancing product durability and facilitating resource recirculation, and reducing the overall system’s size via sustainable production and consumption practices (Korhonen et al., 2018; Su et al., 2013). Based on this context, adopting circular models requires reducing the extraction of virgin resources, extending product lifespans through repair or remanufacturing, and minimizing waste by reintroducing materials into the production cycle (Henry et al., 2020).

In Indonesia, this paradigm shift is particularly relevant given the abundant natural resources, fast-growing population, and the pressing need to minimize environmental degradation. Previous research shows the importance of an ecosystem approach in accelerating CE adoption, emphasizing the synergy among government bodies, private sectors, non-profit organizations, research institutions, and local communities (Ranta et al., 2018; Zucchella & Urban, 2019). Recent studies highlight that collaboration within a robust institutional framework can provide eco-innovation, reduce waste, and optimize resource use, ensuring that sustainable practices are implemented in all layers of economic and social activities (Re et al., 2023; Scott, 2013). Adopting this holistic model requires conducive policies, financial incentives, and shifts in societal attitudes (Korhonen, 2001; North, 1990). The Ministry of National Development Planning Agency (2022) in Indonesia reports that the circular economy strategy has been integrated into key sectors, showcasing varied initiatives that uphold the principles of Reduce (R2), Repurpose (R7), and Recycle (R8) (Ministry of National Development Planning Agency, 2022). MYCL (Mycotech Lab), for instance, utilizes agricultural waste to cultivate mushroom-based materials, demonstrating R2 (Reduce), R7 (Repurpose), and R8 (Recycle) principles in the operations (Mycotech Lab, n.d.). SukkhaCitta implements a farm-to-closet concept in sustainable fashion, emphasizing regenerative agriculture and natural dyes to minimize chemical usage (SukkhaCitta, n.d., 2021). Meanwhile, state-owned enterprises such as PT Pertamina (Persero) have integrated circular economy elements to curb carbon emissions and operational costs (Pertamina, 2023), and the Ministry of Public Works and Housing (PUPR) has constructed green buildings that cut energy and water consumption (Ministry of Public Works and Housing, 2012). In the food sector, Burgreens and BulkSource champion zero-waste strategies through plant-based menus and bulk retail practices, respectively. Anomali Coffee further reduces single-use plastic waste by transitioning to paper-based packaging, whereas the Lingkar Temu Kabupaten Lestari (LTKL) initiative unites various districts to capitalize on local resources while preserving ecosystems.

These diverse case studies collectively highlight that CE success in Indonesia depends on collaborations that span the entire production-consumption chain (Ministry of National Development Planning Agency, 2022). However, there are also challenges. Findings from cross-national comparisons in Finland and Italy, effective circular entrepreneurship is tightly bound to enabling institutional environments (Re et al., 2023). In contexts where regulations are ambiguous or sociocultural norms remain resistant to novel models, CE ventures may struggle to secure resources or consumer acceptance (Ranta et al., 2018; Zeng et al., 2017). By contrast, when political, financial, and cultural incentives align, businesses gain the confidence to experiment with regenerative processes, leading to system-wide changes in both resource efficiency and waste management (Zucchella & Urban, 2019). Based on this background, the implementation of CE principles in Indonesia must be examined with the understanding that local conditions, such as market fragmentation, varied levels of environmental awareness, and administrative overlaps, can either facilitate or hinder eco-innovation (Alka et al., 2024). While the initiatives are promising, a more comprehensive analysis is required. The investigation would compare Indonesia's progress to global exemplars, identifying the drivers, replicable success factors, and persistent barriers. Consequently, insights observed from this comparison could inform future policy interventions, guide investors toward sustainable growth opportunities, and enable local communities to more seamlessly integrate CE solutions. This article thus aims to analyze the efficiency and effectiveness of CE adoption in Indonesia through an ecosystem approach and compare the findings against international benchmarks in order to reach sustainable development and guide future policy decisions.

1.1 Circular economy theories with an emphasis on ecosystems

A central premise of the circular economy (CE) is that economic activities should remain within the regenerative and assimilative capacities of the Earth's ecosystems (Suárez-Eiroa et al., 2019). While traditional linear economic models emphasize a "take-make-dispose" approach, CE highlights regenerative processes that maintain or restore ecosystems' vitality by aligning resource extraction with natural renewal rates and ensuring waste outputs do not exceed ecosystems' absorptive limits (Daly, 1990; Suárez-Eiroa et al., 2019). This shift recognizes that maintaining ecological integrity is essential not just for environment, but also for sustaining long-term economic viability and social well-being (Rockström et al., 2009; Steffen et al., 2015). The theoretical underpinnings of CE emphasize its interdependence with broader notions of sustainable development, particularly the idea that human progress must not compromise future generations' abilities to meet their own needs (Murray et al., 2017; WCED (World Commission on Environment and Development), 1987). In this context, Suarez-Eiroa et al. (2019) argue that CE is most effectively understood as a tool within the sustainable development framework (Suárez-Eiroa et al., 2019). By focusing on ecological processes (i.e. nutrient cycles, biodiversity preservation, and waste assimilation), CE strategies aim to harmonize industrial and societal demands with the planet's finite ecological boundaries (Kirchherr et al., 2017; Suárez-Eiroa et al., 2019). This perspective views ecosystems not as infinite sources of materials and sinks for pollution, but as delicate, interlinked systems with definable (albeit dynamic) thresholds (Rockström et al., 2009).

Within these ecological limits, CE theory further proposes seven operational principles that guide implementation across different scales, i.e. micro (individual firms), meso (eco-industrial networks), and macro (cities, regions, nations) (Suárez-Eiroa et al., 2019). Four of these principles (adjusting inputs to regeneration rates, adjusting outputs to nature's absorption capacity, closing resource loops, and preserving resource value) are necessary for maintaining ecosystem health. By emphasizing the minimization of non-renewable resource use and the reduction of technologically non-recyclable waste, CE encourages practices such as renewable energy adoption, resource-efficient production, and design innovations that enhance durability and ease of repair or recycling (Braungart et al., 2007; Ellen MacArthur Foundation, 2015). In turn, these efforts contribute to reducing the total flow of materials that ecosystems must either regenerate or absorb. Thus, CE's ecosystem-centered theories rely on recognizing that economic activities must be embedded in, rather than separate from, the broader biophysical environment (Suárez-Eiroa et al., 2019) . Through designing products and processes that reflect nature's cyclical patterns, and by educating stakeholders about sustainable consumption and production, CE aspires to protect ecological integrity while simultaneously promoting innovation and economic resilience. The emphasis on ecosystem regeneration emphasizes that each stage in the product life cycle (i.e. resource extraction, production, distribution, consumption, and waste management) can be reimagined to preserve or restore natural capital, thus creating a more harmonious relationship between human needs and Earth's life-support systems.

2. Method

This study used a review approach to analyze the implementation and efficiency of circular-economy (CE) principles in Indonesia within a global comparative framework. The methodology comprises four main steps: literature identification, selection, data extraction, and synthesis & analysis. A comprehensive search was conducted across five electronic databases, such as Scopus, Web of Science, Google Scholar, ScienceDirect, and ProQuest. Search terms combined keywords and Boolean operators to capture CE and ecosystem concepts, for example:

("circular economy" OR "circular-economy" OR "CE")
AND (ecosystem OR "ecosystem approach" OR "eco-industrial")
AND (Indonesia OR "developing countries" OR "global comparison")
To ensure currency, additional searches targeted policy documents and reports from key international bodies (Ellen MacArthur Foundation, European Commission, UNIDO, AfDB).

Identified records were screened in two stages. First, titles and abstracts were reviewed to remove duplicates and irrelevant studies (e.g., purely linear waste management, non-ecosystem CE). Second, full texts were assessed using these criteria: 1) Inclusion, empirical or review studies addressing CE implementation with an ecosystem perspective; case studies from Indonesia or major CE initiatives in Europe, China, Africa, and other benchmarks; policy analyses; published in English or Bahasa Indonesia. 2) exclusion, studies lacking operational details; non-peer-reviewed opinion pieces (except official policy reports); articles focused solely on narrow technical processes without ecosystem context.

2.1 Data extraction, synthesis and comparative Analysis

From each selected work, the following information was systematically recorded in a standardized matrix: 1) author(s), year, and country/region; 2) sector(s) studied (e.g., energy, textiles, waste management); 3) perational CE principles applied (input/output adjustment, loop closing, value preservation); 4) ecosystem elements emphasized (e.g., nutrient cycling, biodiversity, soil & water services); 5) key outcomes and metrics (e.g., emission reductions, material savings, job creation); 6) nabling conditions and barriers (institutional, financial, cultural); eplication and scaling strategies.

Extracted data were synthesized thematically to identify (a) the degree and modes of CE-ecosystem integration in Indonesia, and (b) enabling factors and barriers compared to global exemplars. A cross-case matrix facilitated direct comparison across six domains: policy framework, institutional collaboration, financing mechanisms, technological innovation, community engagement, and monitoring & evaluation. Quantitative outcomes (e.g., recycling rates, CO_2 reductions) were tabulated alongside qualitative insights (e.g., stakeholder dynamics, cultural acceptance). Finally, gaps between Indonesia's pilot-scale, sector-specific initiatives and the comprehensive, economy-wide strategies observed in the EU, China, Finland, and the African CE Alliance were analyzed.

3. Results and discussion

3.1 Circular economy initiatives in indonesia and the comparison with global

Table 1 presents various circular economy initiatives in Indonesia. Meanwhile, table 2 summarizes global circular economy initiatives across multiple sectors. These initiatives showcasing innovative strategies to enhance resource efficiency, minimize waste, and promote sustainability. Table 1 highlights circular economy initiatives in Indonesia, focusing on innovative practices in the textile and fashion sectors. Examples include MYCL's utilization of agricultural waste for mushroom-based materials and SukkhaCitta's transparent supply chain model, both contributing to carbon reduction and increased farmer income. However, these initiatives face challenges such as limited funding, high production costs, and seasonal raw material variability.

Table 1. Circular Economy Initiatives in Indonesia

No.	Initiative & Actor	Sector	Implementation of Circular Economy Principles	Main Impact	Challenges	Replication Strategy	References
1	MYCL (Mycotech Lab) Biotechnology Company	Textiles / Materials	R2 (Reduce): - Converting agricultural waste (oil palm bunches, sugarcane bagasse, etc.) into mushroom growing media. R7 (Repurpose): - Reprocessing mushroom and agricultural waste into value-added products (Mylea, Biobo). R8 (Recycle): - Almost zero waste; solids become Biobo, liquid waste is used as a bioplastic nutrient.	- Reduction of carbon emissions by up to 81% (production efficiency). - Resource savings (reducing mushroom leather production time to 5 days, using less water & CO_2 compared to cow leather). - Utilizing 373 kg of agricultural waste per month.	- Limited funding for biotechnology research & IP protection. - Local consumers are more price-sensitive. - Risk of contamination in mushroom cultivation & pandemic impacts.	- Research & Innovation: Utilizing mushrooms as material. - Attractive Design: Mylea (mushroom leather) & Biobo (panels) with competitive value. - Collaboration: Seeking funding support & lab testing (EU, DBS Foundation, etc.).	(Mycotech Lab, n.d.)
2	SukkhaCitta (Farm-to-Closet Concept)	Textiles / Fashion	R1 (Rethink): - Transparent supply chain (from farmers to	- Increasing farmers' income (by 100%) & female artisans' income	- High cost due to manual processes & natural materials.	- Transparent Supply Chain: Educating consumers on social &	(SukkhaCitta, n.d., 2021; Tania & Meiden, 2024)

No.	Initiative & Actor	Sector	Implementation of Circular Economy Principles	Main Impact	Challenges	Replication Strategy	References
			consumers). R7 (Repurpose): - Fabric scraps used as labels/buttons or packaging lining. R8 (Recycle): - Using leftover fabric, recycled yarn.	(by 60%). - Avoiding 10,000+ pieces of packaging. - Water conservation (1.2 million liters of water saved from contamination). - Reforestation of 20 ha of land through farming.	- Consistency of raw materials & natural dyes (affected by seasons). - Coordination and distribution challenges.	environmental impact. - MadeRight Supply Platform: Facilitating other brands to source materials. - Consumer Education: Explaining the value behind the price & process.	
3	PT Pertamina (Persero)	Energy	R2 (Reduce): - Energy & water efficiency (Beyond Compliance, 5RTD). Circular Carbon Economy: - 4R (Reduce, Reuse, Recycle, Remove), CCUS (Carbon Capture, Utilization, Storage). Renewable Energy: - Geothermal, B30/B100.	- Operational cost savings > IDR 405 billion (2019–2021). - Reduction of CO_2eq emissions by 352,483.42 tons. - Utilization of hazardous & non-hazardous waste (reduced 64.97 tons of hazardous waste & 10.7 tons of non-hazardous waste). - Water conservation of 75,750 m^3 (2019–2021).	- Aligning new renewable energy (NRE) projects with government policies. - New technologies (CCUS) require large investments & risk becoming outdated. - Challenges in internal & external collaboration.	- Joint R&D and Technology: Studies on converting CO_2 into PCC (precipitated calcium carbonate). - Multi-Stakeholder Collaboration: Synergy with government, researchers, society. - Accelerating NRE: Targets for geothermal, gasification, etc., can be adopted by other companies.	(Pertamina, 2023)
4	Ministry of Public Works and Housing (Green Building Concept)	Construction	R2 (Reduce): - Energy efficiency (natural lighting, automatic sensors, air circulation). R8 (Recycle): - Rainwater harvesting & grey water reuse	- Energy savings of up to 181 kWh/m^2/year (below the 240 kWh/m^2 threshold). - Reduction of 29.472 tons of CO_2 per year. - Up to 60% water savings. - Achieved Platinum	- Consistent supervision across 17 floors. - Documentation & maintenance (poor data can lead to wrong maintenance decisions). - Renovation &	- Regulation & Education Outreach: Encouraging other offices to follow suit. - Walk the Talk: Providing direct examples through the green building. - User Engagement:	(Ministry of Public Works and Housing, 2012; the Ministry of Finance of the Republic of Indonesia, 2024)

No.	Initiative & Actor	Sector	Implementation of Circular Economy Principles	Main Impact	Challenges	Replication Strategy	References
			(irrigation, toilet flushing, cooling tower).	Greenship & Subroto Award (environmental recognition).	coordination needed to maintain green building standards.	Involving building occupants (turn off lights/AC, etc.). - Smaller Scale: Application in households.	
5	Burgreens (Plant-Based Restaurant)	F&B	R1 (Rethink): - Replacing animal meat with plant-based ingredients. - Social enterprise approach (values, environment, empowerment). R2 (Reduce): - Lower emissions & water usage (plant-based vs. beef production). - Minimizing production waste.	- CO_2 reduction of 1.1 million kg. - Empowering farmers (IDR 2.3 billion/year for farmers & artisans). - Educating 10,000+ people on healthy, low-waste diets. - Saving IDR 15–25 million/month in operational costs (optimizing ingredients).	- Higher production costs & quality control for plant-based ingredients. - Educating consumers to be willing to pay more. - Coordination with small-scale farmers requires time & consistent quality.	- Waste Management Collaboration: Partnerships with waste banks, recycling startups, etc. - Creative R&D on Raw Materials: Utilizing mushroom residue, banana peels, etc. - Impact Measurement: Data on emissions & waste for marketing. - Integrating Social Values: Fair prices for farmers & employees.	(Burgreens, n.d.)
6	BulkSource (Zero-Waste Grocery)	Retail	R2 (Reduce): - Encouraging customers to bring their own containers, reducing single-use plastic packaging. R3 (Reuse): - Providing reusable containers & ordering products in bulk (minimizing secondary packaging).	- 2,200 tons of plastic avoided over 3 years. - 4 tons of waste prevented from entering landfills (2021). - 10–40% cost savings in distribution. - Employing 25 workers (80% women), 5% of profits allocated to mangrove rehabilitation.	- Quality & humidity control for bulk products. - Difficulty implementing "bring your own container" concept for online orders. - Lack of public awareness about bulk shopping without packaging.	- Collaboration & Education: Active campaigns on social media, physical stores. - Service Diversification: Online sales with eco-friendly packaging. - Stock Management: Controlling temperature & containers based on demand. - Impact Reporting:	(BulkSource, n.d.)

No.	Initiative & Actor	Sector	Implementation of Circular Economy Principles	Main Impact	Challenges	Replication Strategy	References
						Documenting data on waste & emissions.	
7	Anomali Coffee (Plastic Packaging Reduction)	F&B (Coffee)	R2 (Reduce): - Switching to paper cups (butterfly cup) without plastic lids & straws. R3 (Reuse): - Discounts for customers bringing their own tumblers. - Using unsold coffee to make iced palm sugar coffee (reducing ingredient waste).	- Reduction of plastic: 593 kg (cups), 338 kg (lids), & 32.9 kg (straws) in 6 months. - Purchases of IDR 5 billion worth of coffee beans directly from farmers (IDR 1.5 billion for women farmers). - Creating 100 jobs, improving livelihoods for 1,725 farmers.	- Highly competitive coffee market. - Higher costs for paper cups & not fully spill-proof. - Consumer behavior: Price & convenience are still top priorities.	- Packaging Vendor Collaboration: Foodpak, The Earth Keeper. - Consumer Education: The #NgopiMembumi campaign on paper cups. - Local Empowerment: Using local Indonesian coffee beans. - Sustainable Promotions: Tumbler discounts, loyalty programs, etc.	(Anomali Coffee, n.d.)
8	Lingkar Temu Kabupaten Lestari (LTKL) Collaboration of 9 Districts	Community / Multi-Sector	R1 (Rethink): - Development of jumputan gambo (natural dye from gambir), snakehead fish (ikan gabus) in peatlands. R2 (Reduce): - Reducing plastic waste in the production process & albumin production from snakehead fish. R7 (Repurpose): - Gambir residue & leftover fish heads used	- Additional income for farmers & artisans: - Gambir: +IDR 2 million/month. - Snakehead fish: +IDR 15 million/month per group. - Minimizing waste: 95 kg of fish waste reduced to zero, peatlands remain wet. - Empowering women in crafts & processing (30% of staff).	- Limited knowledge & infrastructure (snakehead fish farming, albumin lab). - Optimal use of leftover catechin from gambir is not yet maximized. - Decrease in demand for jumputan fabrics (a tertiary need).	- Jurisdictional Approach (Sustainable District): Integrating regulations, planning, multi-stakeholder involvement, and action. - Collaboration: Engaging government, communities, research, private sector. - Product Diversification & Education: Turning waste into derivative products (garum, fertilizer), public campaigns.	(LTKL, n.d.)

No.	Initiative & Actor	Sector	Implementation of Circular Economy Principles	Main Impact	Challenges	Replication Strategy	References
			as fertilizer & garum (fish-based seasoning).				
9	Asia Pacific Rayon (APR) Private Sector (Viscose Fiber Production)	Textiles	- R2 (Reduce): Reducing carbon footprint, water usage, waste, and sulfur emissions. - R6 (Remanufacture): Reprocessing textile waste into new viscose fibers. - R8 (Recycle): Building infrastructure to collect and recycle textile waste in collaboration with industry partners.	- Reducing carbon footprint by up to 50%/ton VSF. - Cutting waste from 95.99 kg/ton VSF (2019) to 74.08 kg/ton VSF (2021). - Lowering water usage from 49.97 m^3/ton (2019) to 37.48 m^3/ton (2021). - Decreasing sulfur emission intensity from 30.98 kg/ton (2019) to 17.51 kg/ton (2021). - Improving wastewater quality (increasing oxygen levels, reducing TSS). - Reducing energy intensity from 26.54 GJ/ton (2019) to 24.81 GJ/ton (2021). - Using 100% renewable energy since 2020.	- High investment costs for long-term R&D and technology. - Dependence on global policies such as export-import restrictions or lockdowns affecting international distribution. - Technological complexity (closed-loop, blockchain) requires specialized expertise and adequate infrastructure.	- Long-Term Commitment & Sustainable Funding (e.g., Royal Golden Eagle investing USD 200 million over 10 years). - R&D and Technology Development (closed-loop production, blockchain for traceability). - Cross-Industry Collaboration (yarn, fabric, retail) to collect textile waste. - Transparency & Accountability through blockchain technology "Follow Our Fiber." - Community Empowerment (batik artisans, training women & youth in textile centers).	(APR, n.d.)

Table 2 presents a global perspective, showcasing the EU Circular Economy Action Plan as a comprehensive policy model. Implemented since 2015, it has significantly advanced recycling, job creation, and plastic reduction across Europe. Despite notable achievements, the EU still faces challenges in scaling material reuse and addressing sectoral transition gaps.

Table 2. Global Circular Economy Initiatives

Initiative & Actor	Sector	Implementation of CE Principles	Main Impact	Challenges	Replication Strategy	References
EU Circular Economy Action Plan (European Commission)	Economy-wide (Policy)	Adopted in 2015 with 54 measures covering entire product lifecycles, from eco-design and production to consumption, waste management, and secondary markets. Included a Plastics Strategy, funding for innovation, new waste laws (e.g. mandating municipal waste separation), and an EU monitoring framework to close the loop.	Fully delivered by 2019, spurring EU-wide recycling targets (e.g. 70% recycling for packaging by 2030) and bans on single-use plastics. Created jobs (4+ million in CE sectors, +6% since 2012) and €147 billion value added in 2016. The EU became a global leader in CE policymaking, prompting at least 14 EU countries, 8 regions, and 11 cities to adopt their own CE strategies.	Transition gaps remain, as of 2019 only ~12% of materials used in the EU came from recycled sources. Further efforts needed to address hard-to-circular sectors and to achieve climate-neutrality, highlighting the challenge of scaling from waste management to full circular design.	The EU actively exported its CE model: it spurred national roadmaps within Europe and launched the Global Alliance (GACERE) to promote CE internationally. Its policies (e.g. on plastics) set benchmarks that influenced regulations worldwide, and its open data/indicators help other countries track CE progress.	(EDA, 2022; European Commission, 2019; UNIDO, 2024)
China "Zero-Waste City" Pilot (State Council/MEE)	Urban Waste Management	Pilot programme in 11 cities to minimize solid waste generation and maximize recycling. Cities implemented comprehensive waste sorting, recycling facilities, and industrial symbiosis to treat waste as resources. Emphasis on reducing landfill, promoting composting of organics, and circular use of construction waste in these urban labs.	Aimed to cut pollution and greenhouse emissions by embedding CE in city planning. Early results include improved household waste separation rates (e.g. Shenzhen's recycling of residential waste increased) and new resource recovery parks. These pilots built models for urban circular systems, informing China's national policies (e.g. mandatory waste sorting in 46 cities).	Rapid urbanization and consumer culture strain waste systems, cities faced insufficient recycling infrastructure and enforcement. Implementation gaps and regional disparities made it challenging to scale best practices uniformly. Ensuring public participation and overcoming throwaway habits remain key hurdles noted by officials.	China plans to roll out zero-waste practices nationwide: lessons from the 11 pilots (technologies, regulations) are being replicated in other cities. The pilots fed into the national Circular Economy and Waste Management Law revisions, and China is sharing its model via platforms like the Belt and Road Initiative to help other developing cities adopt similar circular waste approaches.	(CACE, 2019; Su et al., 2013; Tian et al., 2025; Zhu et al., 2014)

Initiative & Actor	Sector	Implementation of CE Principles	Main Impact	Challenges	Replication Strategy	References
African Circular Economy Alliance (ACEA) (Rwanda, Nigeria, South Africa + AfDB)	Multi-sector (Policy & Innovation)	Government-led coalition (launched 2017) to promote circular practices across Africa. Provides a platform for policy dialogue, best-practice exchange, and project incubation, e.g. training on CE, support for startups (biowaste valorization, e-waste recycling), and enabling financing via the African Development Bank. Anchored in national governments but engages business and civil society as partners.	Put circular economy on Africa's agenda: endorsed by African ministers in 2019 and backed by AfDB's $4 million Circular Economy Facility. Countries like Ghana, Côte d'Ivoire joined, and CE is now seen as a driver for green jobs and GDP growth (potential 11 million jobs, +2.2% GDP by 2030). Pilots in member states (e.g. Rwanda's e-waste collection center, Nigeria's plastic recycling initiatives) were launched, signalling continental momentum.	Limited funding and infrastructure in many African countries; need for capacity-building and supportive policy frameworks. Aligning diverse economies under common CE goals is complex, and ensuring a just transition (job security for informal waste pickers, affordability) is crucial. The Alliance must also overcome low awareness in some regions.	Scaling through partnership: ACEA grows membership (5 founding countries to now 13+) and aligns with initiatives like the UN's One Planet Network. It prioritizes sharing localized success stories (e.g. biomass briquettes in Kenya) to inspire replication. The AfDB's facility finances new projects, and ACEA's model has informed other regions (the LAC CE Coalition) to form similar coalitions for collective action.	(ADB, 2024; WEF, 2021b, 2021a)
LAC Circular Economy Coalition (UNEP + Latin American governments)	Multi-sector (Policy & Capacity)	Regional coalition (launched Feb 2021) uniting Latin America & Caribbean nations to transition from take-make-waste to circular models. Coordinated by UNEP, it established a rotating Steering Committee (e.g. Colombia, Peru) to set a common vision, mobilize finance for CE SMEs, and develop policy toolkits. Focus areas include sustainable agriculture, plastics, and	Created the region's first Shared Vision for a Circular Economy (2022) aligning 30+ countries on goals and indicators. Facilitated cooperation and funding: e.g. IDB and World Bank launched CE loans, and countries like Chile and Dominican Rep. began drafting CE roadmaps in line with the coalition's vision. The coalition elevated CE in regional forums (e.g. Forum of Environment	Varied economic contexts and data quality across members pose a challenge to unified action. Many LAC countries face pressing basic waste management issues and lack robust recycling infrastructure. Securing private-sector buy-in and bridging knowledge gaps (what CE means in local contexts) are ongoing challenges. Also, ensuring that small island states and larger economies both	Emphasizes knowledge-sharing and south-south cooperation: members share case studies (e.g. Costa Rica's repair networks) for others to emulate. The coalition partners with global actors (EMF, EU) to adapt international best practices regionally. Its open platform approach is itself replicable, already inspiring dialogues in other regions (e.g. an Asian CE coalition in	(Ellen Macarthur Foundation, 2022; UNEP, 2021)

Initiative & Actor	Sector	Implementation of CE Principles	Main Impact	Challenges	Replication Strategy	References
		manufacturing, with working groups sharing solutions across countries.	Ministers) and kick-started cross-border initiatives (like a regional plastics pact).	benefit equitably requires careful governance.	discussion), and as more LAC nations join, the coalition becomes a template for collaborative CE transition.	
Finland's Circular Economy Roadmap (Sitra & Govt. of Finland)	Economy-wide (National Policy)	World's first national CE roadmap (2016) led by innovation fund SITRA. It defined focus areas: sustainable food systems, forest-based loops, technical loops (manufacturing), transport, and common actions (education, innovation). Implementation was collaborative, over 1,000 experts and citizens contributed ideas. The roadmap set qualitative targets (Finland as a global CE leader by 2025) and pilot projects, later evolving into a governmental CE program (2021) aiming for a carbon-neutral circular economy by 2035.	Kickstarted Finland's transition: dozens of pilot projects (from nutrient recycling in agriculture to product-service systems in industry) were launched. Studies estimate full circular adoption could add €2–3 billion to Finland's economy by 2030 and create 75,000 jobs. By framing CE as an economic opportunity, the roadmap secured cross-party support. Finland now consistently ranks high in CE readiness and hosts the annual World Circular Economy Forum, reflecting its role as a CE pioneer.	Despite early mover advantage, Finland found that decoupling material use from growth is tough: by 2021, its raw material consumption was roughly unchanged from 2015, indicating the need for stronger measures. Many gains so far were in recycling, while harder changes (product design, new business models, consumer behavior) lag. Scaling local pilots to system level and integrating circular metrics into all sectors (e.g. mining, construction) remain challenging.	Finland's roadmap became a template internationally, Sitra published it openly and advised other countries (Netherlands, Canada, Taiwan, among others) in crafting their strategies. Finland also forged the Circular Economy Coalition for Finnish municipalities to replicate national goals locally. Through forums like WCEF, Finland actively shares tools and lessons, accelerating replication of its education programs and policy frameworks (e.g. a Circular Economy playbook for governments).	(SITRA, 2016; WEF, 2021a)
"Circular Netherlands 2050" Program (Government of the Netherlands)	Economy-wide (National Policy)	Government-wide circular economy programme (2016) aiming for 50% reduction in primary raw material use (minerals, metals, fossil) by 2030 and 100% circularity by	Institutionalized circular thinking: created platforms like Holland Circular Hotspot to connect businesses and share Dutch expertise globally. The Netherlands	A 2022 review found limited overall progress: despite many initiatives, the Dutch economy was still mainly linear with raw material use in 2010–2020 barely declining. The	The Netherlands actively exports its circular approach: through NL Platform & Holland Circular Hotspot, it collaborates internationally (sharing	(Dutch Ministry of Foreign Affairs, n.d.; The Ministry of Infrastructure and the Environment and the Ministry of

 https://doi.org/10.61511/seesdgj.v3i1.2025.1887

Initiative & Actor	Sector	Implementation of CE Principles	Main Impact	Challenges	Replication Strategy	References
		2050. Implementation via detailed Transition Agendas in 5 sectors: Biomass & Food, Plastics, Manufacturing, Construction, and Consumer Goods. Emphasized producer responsibility, circular design, and circular procurement – the government pledged 10% circular procurement by 2022 and is revising regulations to favor reuse of materials in construction.	boasts one of Europe's highest resource productivity and waste recycling rates (~80% of total waste is recovered). Circular business activity contributed ~€7.3 billion and 118,000 jobs (2018) in sectors like recycling and repair. The program also influenced EU policy (the ambitious Dutch 2030 target paralleled the EU's 2030 goals) and made the Netherlands a living lab for circular innovation (e.g. the world's first circular building projects in Amsterdam).	initial focus on recycling needs to broaden to reuse, repair and redesign – socio-economic innovations (new business models, consumer behavior changes) have been insufficient. Meeting the 2030 goal is at risk without intensified and more coercive policy measures (e.g. tax shifts from labor to resources).	knowledge on circular agriculture, water, packaging). Dutch experts help cities like New York and Amsterdam's doughnut model has inspired peer cities. Regionally, the Netherlands partners with EU neighbors on circular value chains (e.g. Benelux CE collaboration). Thus, the strategy for replication is leading by example and forging international partnerships to implement Dutch solutions elsewhere, aiming to go beyond national borders for a global circular transition.	Economic Affairs, 2016)
Amsterdam Circular City Strategy (City of Amsterdam)	City (Construction, Food, Consumer Goods)	Municipal strategy (2020–2025) to become 100% circular by 2050, using Kate Raworth's Doughnut Economics as a framework. The city targets three key value chains: food & organic waste, consumer goods, and built environment. Implementation includes halving virgin material use by 2030 through actions like circular public procurement (cutting	Amsterdam is a pioneer city in CE: it was the first to commit to full circularity by 2050. Its actions have led to tangible results: e.g. 10% of municipal procurement spend was circular by 2022, dozens of buildings are being constructed to circular standards (with high reused content), and household organic waste collection rates improved markedly. The city's	Measuring impact and scaling pilots citywide is challenging. Some initiatives (like local sharing platforms) see great niche success but need broader citizen adoption to significantly reduce consumption. Data collection across the city's economy is complex, though ongoing (contractors now report material reuse data). Also, aligning all stakeholders –	Amsterdam's strategy is openly documented so other cities can copy it – and many are following. Amsterdam co-founded the Circular Cities Declaration network and shares its Doughnut-based policymaking approach via C40 and EUROcities. The city actively hosts international delegations and contributes to EU urban policy so that its pilots (such as circular	(Ellen Macarthur Foundation, 2024)

Initiative & Actor	Sector	Implementation of CE Principles	Main Impact	Challenges	Replication Strategy	References
		city's own consumables 20% by 2030), material passports for buildings, urban gleaning programs for food waste, and support for sharing economy and repair services (libraries of things, fashion for rent). The city developed open-source monitoring tools to track progress and adjust policies in real-time.	holistic approach earned it recognition as an Earthshot Prize finalist in 2022 for "Waste-Free World". Moreover, Amsterdam's open tools (Circular Monitor, City Doughnut) have been shared and adopted by other cities, multiplying its impact.	from residents to big businesses in the city – requires continuous engagement. Funding the transition (especially for costly retrofits in construction) remains a hurdle, and the city depends on national/EU policy support for tougher measures (like extended producer responsibility) that lie outside municipal authority.	construction standards) become EU-wide norms. In effect, Amsterdam uses open-source urban planning – its methodologies and data (open-access tools) allow any city globally to replicate and adapt the interventions, accelerating a worldwide urban circular movement.	

 https://doi.org/10.61511/seesdgj.v3i1.2025.1887

3.2 Gap analysis

Indonesia has made notable strides in applying circular-economy principles across diverse sectors, from biotechnology and fashion to energy and construction. However, these efforts remain largely fragmented and pilot-scale. Whereas global leaders like the European Union and China operate under unified, economy-wide frameworks with binding targets, Indonesia's initiatives are guided by sectoral policies without an overarching national roadmap. For example, Pertamina's circular-carbon program delivers CO_2 reductions and cost savings, and Mycotech Lab's bioplastic innovation transforms agricultural residues into high-value materials. Yet, without harmonized indicators or enforceable regulations, these successes do not aggregate into a coherent national performance picture. To close this policy gap, Indonesia needs a comprehensive circular-economy law that sets clear targets, such as recycling rates or virgin-material reduction, backed by standardized monitoring and public reporting. In addition, the scale and geographic reach of Indonesia's circular projects also lag behind global benchmarks. Internationally, the EU's Action Plan covers all 27 member states with 54 measures spanning product lifecycles, while China's "Zero-Waste City" pilots embed waste-sorting infrastructure in major and mid-sized cities alike. In contrast, Indonesia's most impactful programs are concentrated in urban centers like Jakarta or within select districts (e.g. the LTKL multi-district collaboration), leaving rural areas and small-to-medium enterprises largely untouched. Expanding source-separation facilities, industrial symbiosis parks, and zero-waste retail models beyond early adopters will be necessary to broadening the circular transition.

Financing remains another critical aspect. Although corporate R&D budgets and ad-hoc government grants support ventures such as APR's closed-loop textile recycling and SukkhaCitta's farm-to-closet model, Indonesia lacks dedicated circular-economy investment vehicles. By contrast, Finland's SITRA fund and the African Development Bank's US$4 million Circular Economy Facility provide sustained, blended finance for pilots and scale-ups. Establishing a national CE fund, issuing green or CE-labelled bonds, and tapping multilateral development bank resources could mobilize the capital needed for large-scale infrastructure and technology adoption. Furthermore, business-model innovations in Indonesia, such as BulkSource's zero-waste grocery and Anomali Coffee's reusable-tumbler incentives, demonstrate local creativity but rely primarily on voluntary participation. Global best practices employ mandatory extended-producer-responsibility schemes, deposit-return systems, and circular public procurement mandates to shift both producer and consumer behavior at scale. Introducing EPR regulations for packaging and electronics, alongside government procurement criteria that favor circular products, would create market signals driving design-for-recyclability and life-extension services.

Finally, social and cultural dimensions of the circular economy require strengthening. While grassroots campaigns (#NgopiMembumi) and community workshops (LTKL) raise awareness among urban consumers, there is no national education strategy embedding circular principles into school curricula or formal recognition of informal recyclers. Models like the African Circular Economy Alliance show the value of including informal-sector actors in policy dialogue and providing social safeguards. Indonesia should therefore convene a multi-stakeholder CE alliance (uniting government, industry, finance, academia, and waste-picker cooperatives) to co-design inclusive strategies, share best practices, and ensure a just transition. By establishing these elements into a cohesive national framework (complete with binding targets, robust financing, mandatory EPR, expanded infrastructure, and inclusive governance), Indonesia can evolve from isolated pilots to a mature circular economy that rivals global exemplars.

3.3 Circular economy strategies for combating environmental issues

The growing global emphasis on mitigating climate change and controlling environmental degradation has stimulated interest in CE strategies as a path toward sustainability (Yang et al., 2023). Modern industrial processes, driven by rapid urbanization and population growth, have led to increased resource extraction, fossil fuel combustion, and solid waste generation (Chen et al., 2022). In turn, these practices intensify greenhouse gas (GHG) emissions, threaten air and water quality, and deplete finite natural resources (Fawzy et al., 2021). Considering these conditions, the CE framework advocates for closing the loop on material and energy flows by emphasizing waste reduction, resource recovery, and the regeneration of natural systems (Ghisellini et al., 2016).

3.4 Circular economy in waste management

A foundation of CE is the rethinking of how waste is generated, processed, and reintegrated into production cycles. Traditional linear models (where raw materials are extracted, products are made and used, and then discarded), contribute to surging landfill volumes and escalating pollution (Guerrero et al., 2013). In contrast, the CE model prioritizes eliminating waste, circulating materials, and regenerating natural ecosystems (Yang et al., 2023). For example the United States generate hundreds of millions of tons of municipal solid waste (MSW) annually, causing management challenges (United States Environmental Protection Agency, 2015). When left unaddressed, these wastes decompose in landfills, releasing large amounts of methane, a potent GHG, while also risking soil and groundwater contamination. CE-driven waste strategies aim to eliminate waste by designing systems so that every output becomes an input elsewhere (Korhonen, Honkasalo, et al., 2018). This vision is embodied in zero-waste frameworks, where cities or regions strive to ensure that no materials end up in incinerators or landfills (Zaman, 2014). In practice, this involves advanced sorting methods, stricter regulations on recyclables, and supportive economic incentives (Phillips et al., 2011). Once waste arises, CE approaches emphasize recovery and recycling routes to transform discarded materials into valuable raw inputs. This is particularly relevant for construction waste, electronic scrap, and packaging plastics, which contain metals, polymers, and other components that can be efficiently retrieved (Abdel-Shafy & Mansour, 2018).

An advantage of these waste-oriented CE strategies is their potential to reduce land-use pressures and lower pollution. Landfill scarcity is already a pressing concern in populous regions (Song et al., 2015), and converting landfills or dumpsites into resource recovery hubs ensures that valuable materials are not locked away. Instead, plastics, metals, glass, and organic matter are recovered and redirected into new production loops (Chen et al., 2019). Together, air and water pollution risks drop when materials are handled in controlled recovery systems rather than open dumps (Silva et al., 2017). By designing products for ease of disassembly, encouraging robust recycling infrastructure, and employing innovations such as composting and bio-digestion for organic fractions, CE-inspired waste management substantially reduces GHG emissions and conserves virgin materials (Yang et al., 2023).

3.5 Circular approaches to industry, energy, and transportation

CE strategies are increasingly influential across industrial operations, from manufacturing to energy generation. Overreliance on fossil fuels and finite raw resources has affected climate change, prompting the industry to seek new approaches that save costs while lowering emissions (Osman et al., 2021). CE interventions in industrial settings typically involve extending product lifespans, improving energy efficiency, and promoting industrial symbiosis, where the by-product of one manufacturing process becomes the feedstock for another (Wang et al., 2019). For example in steel or aluminum plants, large streams of heated exhaust or residual slag can be recaptured and utilized in neighboring facilities, lowering the overall energy needed across the industrial cluster (Cucciniello & Cespi, 2018). These industrial symbiosis tactics are sometimes formalized through eco-industrial parks, strategically grouping facilities so that waste heat, wastewater, and secondary raw materials are systematically exchanged (Fan et al., 2017). The net effect is reduced fossil fuel consumption and fewer emissions across the supply chain (Dong et al., 2013). Furthermore, a CE orientation compels businesses to design for closed-loop recycling from the outset, be it through modular product architectures, greener packaging, or minimal use of hazardous substances that complicate recycling (Payne et al., 2019).

The energy sector itself can also be transformed by CE strategy. On one hand, renewable energy sources such as wind, solar, bioenergy are already displacing carbon-intensive power generation. On the other, CE strategies ensure that technologies like wind turbines or solar panels are built to be recoverable or repurposed (Hao et al., 2020). For example, the composite materials in wind turbines can be reclaimed for new turbines or used in cement coprocessing, reducing the need for virgin materials. Meanwhile, waste-to-energy systems enable electricity and heat production from residual wastes (such as nonrecyclable plastics or agricultural residues), though these should be carefully regulated to avoid undermining higher-value recycling efforts (Fragkos, 2022). Biogas plants that harness the organic fraction of MSW or agricultural manure can likewise produce heat or electricity while supplying nutrient-rich biofertilizers, closing loops in both energy and agriculture (Al-Wahaibi et al., 2020). The transportation sector, which accounts for a large share of global GHG emissions, demands CE-inspired decarbonization pathways (Richter, 2022). Electric vehicles (EVs) and hybrid technologies can lower emissions during the use phase, but also introduce complexities around battery recycling and rare earth metal extraction. Here, CE frameworks emphasize repurposing EV batteries in stationary energy storage systems once they are no longer efficient for vehicular use, or recovering critical metals like lithium, cobalt, and nickel to prevent resource depletion (Paradowska, 2017). At the same time, reimagining roads and rail infrastructures can further embed circularity, e.g., using reclaimed construction aggregates for roads or harvesting waste heat from mass transit systems to provide local building heat (Carpenter et al., 2018). Through robust design and inclusive planning, the transportation sector stands to reap environmental and economic gains from CE-driven resource efficiency (Yang et al., 2023).

3.6 Circular economy in food systems and resource use

Food production and consumption patterns are closely linked to climate change, resource depletion, and waste generation (Borrello et al., 2017). Agricultural intensification often results in soil degradation, water scarcity, and GHG emissions from fertilizers and livestock (Jurgilevich et al., 2016). Meanwhile, more than a billion tons of food are wasted globally every year, emphasizing a high inefficiency in the linear model (Fidélis et al., 2021). CE strategies offer a chance to address these inefficiencies holistically. A core CE concept in agriculture is to design closed nutrient loops. Biowaste that originates on farms or in food processing can be returned to fields as compost or biofertilizer, retaining nutrients like nitrogen and phosphorus (Chojnacka et al., 2020). The production of biochar from agricultural residues, such as straw or fruit pomace, not only sequesters carbon in soil but also improves soil fertility and water retention (Osman et al., 2022). These steps help reduce the reliance on synthetic fertilizers and lower net GHG emissions, thus contributing to climate change mitigation (Leppäkoski et al., 2021). In addition, localizing food production and processing could cut transportation distances and helps minimize spoilage in transit (Bere & Brug, 2009). Adopting dietary shifts that de-emphasize high-impact meats can further lessen the environmental burden (de Boer et al., 2014). Food waste management is especially prominent in CE. Surplus food that remains safe for human consumption can be redistributed via food banks, while inedible fractions can be converted to high-value products like enzymes, bioethanol, or biodegradable materials (Toop et al., 2017). For example, the peel or pulp generated by juice processing can be transformed into dietary fiber, essential oils, and other secondary products (Khanpit et al., 2023). These innovations not only prevent landfill disposal (and thereby cut methane emissions) but also generate new revenue streams for agricultural and manufacturing stakeholders (Diaz-Elsayed et al., 2020). So, a CE approach to food systems streamlines agricultural inputs, expands possibilities for byproduct valorization, and builds resilience against supply chain disruptions, all while lowering the sector's carbon and ecological footprint (Yang et al., 2023).

3.7 Life cycle assessment and cost-effective routes

Life Cycle Assessment (LCA) is a widely used tool that measures the environmental profile of a product or process across its entire life cycle, from raw material extraction, through manufacturing and distribution, to end-of-life (Niero & Olsen, 2016). By pairing LCA with CE principles, practitioners can ensure that new circular solutions do not inadvertently shift impacts or create hidden carbon hotspots (Lu & Halog, 2020). Indeed, multiple studies confirm that LCA reveals both the direct and indirect impacts of circular attempts, guiding improvements that consider energy consumption, water use, GHG emissions, and economic feasibility (Scheepens et al., 2016). Yet, while environmental outcomes often occupy center stage, social and economic dimensions must also be integrated to make the CE truly sustainable (Niero et al., 2021). Governments and industries can use the formation of eco-industrial parks, wherein companies in proximity exchange residues, share utilities, and collaborate on waste recovery measures to reduce costs and emissions (van Bueren et al., 2012). Likewise, scaling up the recycling of construction and demolition waste demands robust, cost-effective pathways. By using advanced sorting systems, creating databases of recycled materials, and standardizing quality for reclaimed aggregates, the building sector can cut raw resource usage and minimize the carbon footprint of new construction (Akanbi et al., 2018). Municipal-level policies, such as mandatory source separation of recyclables, also improve CE transitions by guaranteeing clean material streams for reintegration into production (Zhang et al., 2021). While these measures require an initial investment in infrastructure and public education, the long-term cost savings in landfill avoidance, raw material substitution, and carbon offsetting can be substantial (Liu et al., 2022). Thus, from establishing industrial symbiosis to optimizing end-of-life product processes, many feasible and profitable CE routes exist for tackling climate change and preserving natural resources.

4. Conclusion

This review demonstrates that Indonesia has pioneered a diverse array of circular-economy initiatives, spanning biotechnology, fashion, energy, construction, retail, and community collaboration which collectively embody main ecosystem principles such as loop closing, resource value preservation, and input/output alignment with natural cycles. However, these attempt remain largely fragmented and pilot-scale, lacking a unifying national framework to aggregate sectoral gains into economy-wide performance. In contrast, global leaders like the EU, China, and Finland have deployed binding targets, dedicated funding instruments, and mandatory extended-producer-responsibility schemes, enabling systemic shifts in both policy and practice. For Indonesia to transition from isolated success stories to a mature circular economy, it must establish harmonized indicators, enforceable regulations, and robust financing mechanisms, while promoting inclusive governance structures that engage informal actors and rural communities.

To deepen understanding and guide policy, future studies should undertake primary empirical research, such as life-cycle assessments of Indonesian pilot projects and longitudinal tracking of material-flow indicators to quantify environmental and economic benefits over time. Investigations into financing models (e.g., green bonds, blended-finance vehicles) could reveal pathways to scale infrastructure investments. Ethnographic and survey-based research in rural and informal-sector contexts would explain sociocultural drivers and barriers to circular practices beyond urban centers. Finally, action-oriented case studies on extended-producer-responsibility implementation, circular public procurement, and multi-stakeholder governance platforms are needed to evaluate the transferability of global best practices within Indonesia's unique institutional landscape.

Acknowledgement
The author expresses their gratitude to the reviewers for their valuable and constructive feedback on this article.

Author Contribution

The author contributed equalily to the conceptualization, methodology, analysis, and writing of this review. They collaboratively reviewed and approved the final manuscript for submission.

Funding

This research did not use external funding.

Ethical Review Board Statement

Not available.

Informed Consent Statement

Not available.

Data Availability Statement

Not applicable.

Conflicts of Interest

The author declares no conflict of interest.

Open Access

References

Abdel-Shafy, H. I., & Mansour, M. S. M. (2018). Solid waste issue: Sources, composition, disposal, recycling, and valorization. *Egyptian Journal of Petroleum*, *27*(4), 1275–1290. https://doi.org/10.1016/j.ejpe.2018.07.003

ADB. (2024). *2024 Annual Meetings: The Africa Circular Economy Facility seeks to boost African economies through green growth innovation*. African Development Bank Group.

Akanbi, L. A., Oyedele, L. O., Akinade, O. O., Ajayi, A. O., Davila Delgado, M., Bilal, M., & Bello, S. A. (2018). Salvaging building materials in a circular economy: A BIM-based whole-life performance estimator. *Resources, Conservation and Recycling*, *129*, 175–186. https://doi.org/10.1016/j.resconrec.2017.10.026

Alka, T. A., Raman, R., & Suresh, M. (2024). Research trends in innovation ecosystem and circular economy. *Discover Sustainability*, *5*(1), 323. https://doi.org/10.1007/s43621-024-00535-5

Al-Wahaibi, A., Osman, A. I., Al-Muhtaseb, A. H., Alqaisi, O., Baawain, M., Fawzy, S., & Rooney, D. W. (2020). Techno-economic evaluation of biogas production from food waste via anaerobic digestion. *Scientific Reports*, *10*(1), 15719. https://doi.org/10.1038/s41598-020-72897-5

Anomali Coffee. (n.d.). *Meet the Team*. Anomali Coffee.

APR. (n.d.). *Sustainability*. Aprayon.

Bere, E., & Brug, J. (2009). Towards health-promoting and environmentally friendly regional diets – a Nordic example. *Public Health Nutrition*, *12*(1), 91–96. https://doi.org/10.1017/S1368980008001985

Borrello, M., Caracciolo, F., Lombardi, A., Pascucci, S., & Cembalo, L. (2017). Consumers' Perspective on Circular Economy Strategy for Reducing Food Waste. *Sustainability*, *9*(1), 141. https://doi.org/10.3390/su9010141

Braungart, M., McDonough, W., & Bollinger, A. (2007). Cradle-to-cradle design: creating healthy emissions – a strategy for eco-effective product and system design. *Journal of Cleaner Production*, *15*(13–14), 1337–1348. https://doi.org/10.1016/j.jclepro.2006.08.003

BulkSource. (n.d.). *Powering Material Producers with Smarter Solutions*. BulkSource.

Burgreens. (n.d.). *About Us*. Burgreens.

CACE. (2019). *11 Cities Have Been Selected for "Zero-Waste City" Pilot Program*. China Association of Circular Economy.

Carpenter, A., Lozano, R., Sammalisto, K., & Astner, L. (2018). Securing a port's future through Circular Economy: Experiences from the Port of Gävle in contributing to sustainability. *Marine Pollution Bulletin*, *128*, 539–547. https://doi.org/10.1016/j.marpolbul.2018.01.065

Chen, L., Msigwa, G., Yang, M., Osman, A. I., Fawzy, S., Rooney, D. W., & Yap, P.-S. (2022). Strategies to achieve a carbon neutral society: a review. *Environmental Chemistry Letters*, *20*(4), 2277–2310. https://doi.org/10.1007/s10311-022-01435-8

Chen, L., Wang, L., Cho, D.-W., Tsang, D. C. W., Tong, L., Zhou, Y., Yang, J., Hu, Q., & Poon, C. S. (2019). Sustainable stabilization/solidification of municipal solid waste incinerator fly ash by incorporation of green materials. *Journal of Cleaner Production*, *222*, 335–343. https://doi.org/10.1016/j.jclepro.2019.03.057

Chojnacka, K., Witek-Krowiak, A., Moustakas, K., Skrzypczak, D., Mikula, K., & Loizidou, M. (2020). A transition from conventional irrigation to fertigation with reclaimed wastewater: Prospects and challenges. *Renewable and Sustainable Energy Reviews*, *130*, 109959. https://doi.org/10.1016/j.rser.2020.109959

Cucciniello, R., & Cespi, D. (2018). Recycling within the Chemical Industry: The Circular Economy Era. *Recycling*, *3*(2), 22. https://doi.org/10.3390/recycling3020022

Daly, H. E. (1990). Toward some operational principles of sustainable development. *Ecological Economics*, *2*(1), 1–6. https://doi.org/10.1016/0921-8009(90)90010-R

de Boer, J., Schösler, H., & Aiking, H. (2014). "Meatless days" or "less but better"? Exploring strategies to adapt Western meat consumption to health and sustainability challenges. *Appetite*, *76*, 120–128. https://doi.org/10.1016/j.appet.2014.02.002

Diaz-Elsayed, N., Rezaei, N., Ndiaye, A., & Zhang, Q. (2020). Trends in the environmental and economic sustainability of wastewater-based resource recovery: A review. *Journal of Cleaner Production*, *265*, 121598. https://doi.org/10.1016/j.jclepro.2020.121598

Dong, L., Zhang, H., Fujita, T., Ohnishi, S., Li, H., Fujii, M., & Dong, H. (2013). Environmental and economic gains of industrial symbiosis for Chinese iron/steel industry: Kawasaki's experience and practice in Liuzhou and Jinan. *Journal of Cleaner Production*, *59*, 226–238. https://doi.org/10.1016/j.jclepro.2013.06.048

Dutch Ministry of Foreign Affairs. (n.d.). *Circular economy*. Netherlands.

EDA. (2022). *Construction and Circular Economy*. EDA.

Elia, V., Gnoni, M. G., & Tornese, F. (2017). Measuring circular economy strategies through index methods: A critical analysis. *Journal of Cleaner Production*, *142*, 2741–2751. https://doi.org/10.1016/j.jclepro.2016.10.196

Ellen MacArthur Foundation. (2015). *Delivering the circular economy: A toolkit for policymakers.* Ellen Macarthur Foundation.

Ellen Macarthur Foundation. (2022). *Latin America and the Caribbean Circular Economy Coalition launches a vision for a circular economy for the region*. Ellen Macarthur Foundation.

Ellen Macarthur Foundation. (2024). *Aiming for 100% circularity: Amsterdam*. Ellen Macarthur Foundation.

European Commission. (2019). *Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Implementation of the Circular Economy Action Plan*. European Commission.

Fan, Y., Qiao, Q., & Fang, L. (2017). Network analysis of industrial metabolism in industrial park – A case study of Huai'an economic and technological development area. *Journal of Cleaner Production*, *142*, 1552–1561. https://doi.org/10.1016/j.jclepro.2016.11.149

Fawzy, S., Osman, A. I., Yang, H., Doran, J., & Rooney, D. W. (2021). Industrial biochar systems for atmospheric carbon removal: a review. *Environmental Chemistry Letters*, *19*(4), 3023–3055. https://doi.org/10.1007/s10311-021-01210-1

Fidélis, T., Cardoso, A. S., Riazi, F., Miranda, A. C., Abrantes, J., Teles, F., & Roebeling, P. C. (2021). Policy narratives of circular economy in the EU – Assessing the embeddedness of water and land in national action plans. *Journal of Cleaner Production*, *288*, 125685. https://doi.org/10.1016/j.jclepro.2020.125685

Fragkos, P. (2022). Analysing the systemic implications of energy efficiency and circular economy strategies in the decarbonisation context. *AIMS Energy*, *10*(2), 191–218. https://doi.org/10.3934/energy.2022011

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. *Waste Management*, *33*(1), 220–232. https://doi.org/10.1016/j.wasman.2012.09.008

Hao, S., Kuah, A. T. H., Rudd, C. D., Wong, K. H., Lai, N. Y. G., Mao, J., & Liu, X. (2020). A circular economy approach to green energy: Wind turbine, waste, and material recovery. *Science of The Total Environment*, *702*, 135054. https://doi.org/10.1016/j.scitotenv.2019.135054

Henry, M., Bauwens, T., Hekkert, M., & Kirchherr, J. (2020). A typology of circular start-ups: An Analysis of 128 circular business models. *Journal of Cleaner Production*, *245*, 118528. https://doi.org/10.1016/j.jclepro.2019.118528

Jurgilevich, A., Birge, T., Kentala-Lehtonen, J., Korhonen-Kurki, K., Pietikäinen, J., Saikku, L., & Schösler, H. (2016). Transition towards Circular Economy in the Food System. *Sustainability*, *8*(1), 69. https://doi.org/10.3390/su8010069

Khanpit, V. V., Tajane, S. P., & Mandavgane, S. A. (2023). Orange waste peel to high value soluble dietary fiber concentrate: comparison of conversion methods and their environmental impact. *Biomass Conversion and Biorefinery*, *13*(16), 14413–14423. https://doi.org/10.1007/s13399-022-02481-6

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Korhonen, J. (2001). Four ecosystem principles for an industrial ecosystem. *Journal of Cleaner Production*, *9*, 253–259. https://doi.org/10.1016/S0959-6526(00)00058-5

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*, *143*, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Korhonen, J., Nuur, C., Feldmann, A., & Birkie, S. E. (2018). Circular economy as an essentially contested concept. *Journal of Cleaner Production*, *175*, 544–552. https://doi.org/10.1016/j.jclepro.2017.12.111

Leppäkoski, L., Marttila, M. P., Uusitalo, V., Levänen, J., Halonen, V., & Mikkilä, M. H. (2021). Assessing the Carbon Footprint of Biochar from Willow Grown on Marginal Lands in Finland. *Sustainability*, *13*(18), 10097. https://doi.org/10.3390/su131810097

Liu, Q., Xu, Q., Shen, X., Chen, B., & Esfahani, S. S. (2022). The Mechanism of Household Waste Sorting Behaviour—A Study of Jiaxing, China. *International Journal of Environmental Research and Public Health*, *19*(4), 2447. https://doi.org/10.3390/ijerph19042447

LTKL. (n.d.). *Tentang LTKL*. Kabupatenlestari.org

Lu, T., & Halog, A. (2020). Towards better life cycle assessment and circular economy: on recent studies on interrelationships among environmental sustainability, food systems and diet. *International Journal of Sustainable Development & World Ecology*, *27*(6), 515–523. https://doi.org/10.1080/13504509.2020.1734984

Ministry of National Development Planning Agency. (2022). *The future is circular: Uncovering circular economy initiatives in Indonesia*.

Ministry of Public Works and Housing. (2012). *Gedung Utama PU dengan Konsep Green Building*. https://pu.go.id/berita/gedung-utama-pu-dengan-konsep-green-building

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, *140*(3), 369–380. https://doi.org/10.1007/s10551-015-2693-2

Mycotech Lab. (n.d.). *Sustainability*. MYCL.

Niero, M., Jensen, C. L., Fratini, C. F., Dorland, J., Jørgensen, M. S., & Georg, S. (2021). Is life cycle assessment enough to address unintended side effects from Circular Economy initiatives? *Journal of Industrial Ecology*, *25*(5), 1111–1120. https://doi.org/10.1111/jiec.13134

Niero, M., & Olsen, S. I. (2016). Circular economy: To be or not to be in a closed product loop? A Life Cycle Assessment of aluminium cans with inclusion of alloying elements. *Resources, Conservation and Recycling*, *114*, 18–31. https://doi.org/10.1016/j.resconrec.2016.06.023

North, D. C. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge University Press. https://doi.org/10.1017/CBO9780511808678

Osman, A. I., Fawzy, S., Farghali, M., El-Azazy, M., Elgarahy, A. M., Fahim, R. A., Maksoud, M. I. A. A., Ajlan, A. A., Yousry, M., Saleem, Y., & Rooney, D. W. (2022). Biochar for agronomy, animal farming, anaerobic digestion, composting, water treatment, soil remediation, construction, energy storage, and carbon sequestration: a review. *Environmental Chemistry Letters*, *20*(4), 2385–2485. https://doi.org/10.1007/s10311-022-01424-x

Osman, A. I., Hefny, M., Abdel Maksoud, M. I. A., Elgarahy, A. M., & Rooney, D. W. (2021). Recent advances in carbon capture storage and utilisation technologies: a review. *Environmental Chemistry Letters*, *19*(2), 797–849. https://doi.org/10.1007/s10311-020-01133-3

Paradowska, M. (2017). *Grounds and Challenges for Implementing a Circular Economy in the European Road Transport Sector* (pp. 245–269). In *Suchanek, M. (eds) Sustainable Transport Development, Innovation and Technology*. https://doi.org/10.1007/978-3-319-51427-7_21

Payne, J., McKeown, P., & Jones, M. D. (2019). A circular economy approach to plastic waste. *Polymer Degradation and Stability*, *165*, 170–181. https://doi.org/10.1016/j.polymdegradstab.2019.05.014

Pertamina. (2023). *Laporan Keberlanjutan: Energizing Your Journey towards Sustainability*. Pertamina.

Phillips, P. S., Tudor, T., Bird, H., & Bates, M. (2011). A critical review of a key Waste Strategy Initiative in England: Zero Waste Places Projects 2008–2009. *Resources, Conservation and Recycling*, *55*(3), 335–343. https://doi.org/10.1016/j.resconrec.2010.10.006

Ranta, V., Aarikka-Stenroos, L., Ritala, P., & Mäkinen, S. J. (2018). Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe. *Resources, Conservation and Recycling*, *135*, 70–82. https://doi.org/10.1016/j.resconrec.2017.08.017

Re, B., Henttonen, K., Piispanen, V.-V., & Lehtimäki, H. (2023). The Role of Institutional Environment in Catalysing Circular Entrepreneurship. In *The Routledge Handbook of Catalysts for a Sustainable Circular Economy* (pp. 143–166). Routledge. https://doi.org/10.4324/9781003267492-9

Richter, J. L. (2022). A circular economy approach is needed for electric vehicles. *Nature Electronics*, *5*(1), 5–7. https://doi.org/10.1038/s41928-021-00711-9

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S. I., Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., de Wit, C. A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, *14*(2), art32. https://doi.org/10.5751/ES-03180-140232

Sauvé, S., Bernard, S., & Sloan, P. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, *17*, 48–56. https://doi.org/10.1016/j.envdev.2015.09.002

Scheepens, A. E., Vogtländer, J. G., & Brezet, J. C. (2016). Two life cycle assessment (LCA) based methods to analyse and design complex (regional) circular economy systems. Case: making water tourism more sustainable. *Journal of Cleaner Production*, *114*, 257–268. https://doi.org/10.1016/j.jclepro.2015.05.075

Scott, W. R. (2013). *Institutions and Organizations: Ideas, Interests, and Identities* (Fourth Edition). SAGE Publication, Inc.

Silva, A., Rosano, M., Stocker, L., & Gorissen, L. (2017). From waste to sustainable materials management: Three case studies of the transition journey. *Waste Management*, *61*, 547–557. https://doi.org/10.1016/j.wasman.2016.11.038

SITRA. (2016). *Leading the cycle: Finnish road map to a circular economy 2016–2025*.

Song, Q., Li, J., & Zeng, X. (2015). Minimizing the increasing solid waste through zero waste strategy. *Journal of Cleaner Production*, *104*, 199–210. https://doi.org/10.1016/j.jclepro.2014.08.027

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223). https://doi.org/10.1126/science.1259855

Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production*, *42*, 215–227. https://doi.org/10.1016/j.jclepro.2012.11.020

Suárez-Eiroa, B., Fernández, E., Méndez-Martínez, G., & Soto-Oñate, D. (2019). Operational principles of circular economy for sustainable development: Linking theory and practice. *Journal of Cleaner Production*, *214*, 952–961. https://doi.org/10.1016/j.jclepro.2018.12.271

SukkhaCitta. (n.d.). *About Us*. SukkhaCitta.

SukkhaCitta. (2021). *What is sustainable fashion?* SukkhaCitta.

Tania, L., & Meiden, C. (2024). Analysis of The Form of Sustainable Fashion and The Quality of Disclosure Of Economic, Social And Environmental Aspects On The Website In 2022: A Case Study Of Sukkhacitta.Com. *Jurnal Ekonomi Teknologi Dan Bisnis (JETBIS)*, *3*(4), 802–817. https://doi.org/10.57185/jetbis.v3i4.98

the Ministry of Finance of the Republic of Indonesia. (2024). *Green Building Series: Konsep Green Building*. Ministry of Finance of the Republic of Indonesia.

The Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs. (2016). *A Circular Economy in the Netherlands by 2050: Government-wide Programme for a Circular Economy*. Ministry of Finance of the Republic of Indonesia.

Tian, C., Sui, H., Chen, Y., Wang, W., & Deng, H. (2025). Estimating carbon emission reductions from China's "Zero-waste City" construction pilot program. *Resources, Conservation and Recycling*, *212*, 107975. https://doi.org/10.1016/j.resconrec.2024.107975

Toop, T. A., Ward, S., Oldfield, T., Hull, M., Kirby, M. E., & Theodorou, M. K. (2017). AgroCycle – developing a circular economy in agriculture. *Energy Procedia*, *123*, 76–80. https://doi.org/10.1016/j.egypro.2017.07.269

UNEP. (2021). *Circular Economy Coalition launched for Latin America and the Caribbean*. UN Environment Program.

UNIDO. (2024). *GACERE*. United Nations Industrial Development Organization.

United States Environmental Protection Agency. (2015). *National overview: facts and fgures on materials, wastes and recycling*. United States Environmental Protection Agency.

van Bueren, E., van Bohemen, H., Itard, L., & Visscher, H. (Eds.). (2012). *Sustainable Urban Environments*. Springer Netherlands. https://doi.org/10.1007/978-94-007-1294-2

Wang, N., Guo, Z., Meng, F., Wang, H., Yin, J., & Liu, Y. (2019). The circular economy and carbon footprint: A systematic accounting for typical coal-fuelled power industrial parks. *Journal of Cleaner Production*, *229*, 1262–1273. https://doi.org/10.1016/j.jclepro.2019.05.064

WCED (World Commission on Environment and Development). (1987). *Our Common Future*. Oxford University Press.

WEF. (2021a). *Countries must transition to a circular economy. The right roadmap can help*. World Economic Forum.

WEF. (2021b). *Five Big Bets for the Circular Economy in Africa - African Circular Economy Alliance*.

Yang, M., Chen, L., Wang, J., Msigwa, G., Osman, A. I., Fawzy, S., Rooney, D. W., & Yap, P.-S. (2023). Circular economy strategies for combating climate change and other environmental issues. *Environmental Chemistry Letters*, *21*(1), 55–80. https://doi.org/10.1007/s10311-022-01499-6

Zaman, A. U. (2014). Identification of key assessment indicators of the zero waste management systems. *Ecological Indicators*, *36*, 682–693. https://doi.org/10.1016/j.ecolind.2013.09.024

Zeng, H., Chen, X., Xiao, X., & Zhou, Z. (2017). Institutional pressures, sustainable supply chain management, and circular economy capability: Empirical evidence from Chinese eco-industrial park firms. *Journal of Cleaner Production*, *155*, 54–65. https://doi.org/10.1016/j.jclepro.2016.10.093

Zhang, J., Zhang, Z., Zhang, J., Fan, G., & Wu, D. (2021). A Quantitative Study on the Benefit of Various Waste Classifications. *Advances in Civil Engineering*, *2021*(1). https://doi.org/10.1155/2021/6660927

Zhu, H., Li, Y., Pettersson, B., Zhang, L., Lindström, M., & Henriksson, G. (2014). Technical soda lignin dissolved in urea as an environmentally friendly binder in wood fiberboard. *Journal of Adhesion Science and Technology*, *28*(5), 490–498. https://doi.org/10.1080/01694243.2013.843284

Zucchella, A., & Urban, S. (2019). *Circular Entrepreneurship: Creating Responsible Enterprise*. Palgrave Macmillan.

Biography of Author

Kevin Ibrahim Suryo, School of Environmental Science, Universitas Indonesia, Jakarta, 10430, Indonesia.

- Email: kevin.ibrahim@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A