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Advancing sustainable rural development through circular economy practices: Evidence from SMEs in Central Java, Indonesia

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ABSTRACT

The circular economy (CE) has been widely promoted as a strategy for sustainable development, yet evidence of its implementation among rural small and medium enterprises in developing countries remains limited. This study aims to examine how rural enterprises in Banyumas District, Central Java, Indonesia, adopt CE practices and to identify the challenges and opportunities associated with these practices. Data were collected through focus group discussions, semi-structured interviews and field observations involving 20 participants from various rural enterprises. The data were analyzed using thematic analysis to generate insights into innovative practices. The findings reveal that innovative practices include the use of organic materials, renewable energy generation, and the utilization of industrial by-products. However, significant challenges persist, including a shortage of natural dye raw materials, unstable color quality, high production costs, low local market demand, and limited technical maintenance in biogas facilities. Education, training, and cross-sector collaboration emerge as essential enablers for advancing CE practices in rural SMEs.

Keywords: circular economy, green economy, rural SMEs, sustainability, challenges, opportunities

INTRODUCTION

The concept of the circular economy (CE) has garnered significant attention in recent years as a sustainable alternative to the traditional linear economic model. CE emphasizes resource efficiency, waste reduction, and the continuous use of resources through recycling, reuse, and remanufacturing (Geissdoerfer et al., 2017). While CE is grounded in system theory, industrial ecology, and sustainable development (Ghisellini et al., 2016), these frameworks provide an analytical basis for understanding circular practices in rural MSMEs. System theory suggests how rural enterprises operate within interconnected ecological, social, and economic systems, shaping their decision making and resource flows (Meadows, 2008). Industrial ecology complements this by focusing on material exchange illustrating how by products or waste can be transformed into inputs within rural production networks (Frosch & Gallopoulos, 1989). Sustainable development adds a normative dimension by emphasizing long-term environmental stewardship along with socioeconomic well-being. Taken together, these perspectives can be conceptualized as an integrated framework in which rural MSMEs navigate resource constraints, community relationship, and environmental pressures to generate circular practices.

CE offers innovative solutions for rural MSMEs, enhancing resource efficiency, reducing waste, and promoting operational sustainability (Palombi et al., 2024). For rural MSMEs, CE adoption can strengthen competitiveness, create new business opportunities, and foster community well-being (Rizos et al., 2016; Teo et al., 2023; Uvarova et al., 2019). Research highlights several core CE practices, including resource recovery, product life extension, and sustainable sourcing. Resource recovery reintegrates valuable materials from waste streams, often through innovative waste management or collaboration with local communities (Murray et al., 2017). Product life extension involves designing for longevity and repairability to reduce waste (Bocken et al., 2016). Sustainable sourcing incorporates environmental and social criteria in supplier choices, thereby promoting ethical and eco-friendly practices (Ogunsuji et al., 2024).

Despite the potential benefits of adopting CE practices, rural MSMEs encounter several challenges. These include limited scale, distance from markets and support institutions (Rizos et al., 2016; Uvarova et al., 2019). Additional barriers include regulatory frameworks favoring linear models (Bocken et al., 2016), weak consumer demand for circular products (Hartley et al., 2022; Yerznkyan & Fontana, 2023), and

insufficient knowledge of CE practices (Binek & Al-Muhannadi, 2020; Hossain et al., 2020). Nonetheless, opportunities exist. Rural MSMEs can benefit from collaboration and resource sharing (Kumar & Suganya, 2019; López-Morales et al., 2015), rising consumer awareness of sustainability (Ranta et al., 2018), and government support through financial incentives and training (Hossain et al., 2020; Teo et al., 2023). Creating dedicated green marketplaces and consumer communities can further accelerate the diffusion of CE practices (Rizos et al., 2016).

While previous research has examined CE adoption in MSMEs, many remain urban-centered. Empirical studies on rural MSMEs-especially those embedded with local communities-remain limited. In rural contexts, MSMEs can play a crucial role in fostering growth and promoting sustainable rural development (Berlemann & Jahn, 2016; Korsgaard et al., 2015b; Kranzusch et al., 2017). Unlike their counterparts in metropolitan areas, MSMEs and their owner-managers are often more integrated into their rural communities (Harangozó & Zilahy, 2015; Lang et al., 2014). Consequently, they tend to feel a greater sense of responsibility toward their regions, which encourages them to influence the future positively, create new jobs, pursue community benefits, and drive innovation (Berlemann & Jahn, 2016; Fortunato, 2014; Lang et al., 2014). Additionally, rural areas offer unique historical, cultural, or physical resources (Korsgaard et al., 2015a), creating further opportunities for MSMEs. However, these context-specific dynamics are rarely examined. Empirical insights into industries such as batik, eco-print, or biogas—sectors deeply connected tied to local ecological resources—are particularly scarce.

To address this gap, the present study focuses on rural MSMEs in Banyumas District, Central Java Province, Indonesia, an underexplored yet highly relevant setting for understanding grassroot circular innovation. By adopting a field-based qualitative approach involving focus group discussions (FGDs), interviews, and direct observation, this study extends prior work that often relies on survey-based or conceptual analyses. MSMEs in rural Indonesia are vital to driving economic growth by creating jobs and increasing incomes, especially in areas distant from major economic centers. This study is guided by the following research questions: how do rural MSMEs in Banyumas District develop and implement innovative CE practices? what opportunities and constraints shape CE adoption in rural context? how can policy interventions strengthen rural MSME's transition towards circularity? This paper contributes to the literature by documenting grassroots, context-specific CE innovations among rural MSMEs in Indonesia, a context underexplored in the literature, analyzing the interplay between local opportunities, community embeddedness, and structural barriers to CE adoption, and offering policy-relevant recommendations to support rural enterprises in advancing their circular transition. In doing so, this paper bridges the gap between predominantly urban-focused CE studies and the realities of rural MSMEs.

METHODOLOGY

This study employs a qualitative research design using multiple case studies to gain an in-depth understanding of the implementation of CE in MSMEs, with an emphasis on the innovative approaches used and their sustainability impacts. The study population comprises MSMEs in Banyumas District that are currently implementing the CE concept. Samples were selected through purposive sampling to examine specific cases considered successful or innovative in applying CE. Purposive sampling was used because the study required identifying MSMEs in Banyumas Regency that had already adopted CE practices. Given that CE adoption is still limited and uneven across sectors, probability-based sampling would not have efficiently captured firms with these specific characteristics. By selecting MSMEs that met predefined CE criteria—such as waste reduction, reuse, recycling, or resource-efficient production—the sample remained information-rich and directly aligned with the research objectives. However, purposive sampling may introduce selection bias because the selection relies on the researcher's access to MSMEs known for practicing CE. Less visible firms may have been overlooked, limiting generalizability. To reduce this risk, the study used multiple identification sources, but some bias may still remain.

Ethical considerations were carefully observed in this study. All MSME participants were informed about the purpose of research and procedures, and their voluntary participation was secured through informed consent. Confidentiality was maintained by anonymizing all data and ensuring that no identifying information appeared in the findings. All data were stored securely and used solely for research purposes.

The qualitative instrument used is a semi-structured interview guide designed to explore various aspects of CE implementation, including the innovations applied, the challenges faced, and the impacts on sustainability. Data were collected through various methods:

(1) secondary data collection on the practice of CE implementation in MSMEs available in online mass media and other digital sources,

(2) FGDs involving the research team and 20 selected MSMEs practicing CE,

(3) in-depth interviews with the owners or managers of selected MSMEs to gain insights into their experiences with CE implementation,

(4) field observations to directly observe the operational processes of MSMEs implementing CE for contextual understanding, and

(5) collecting and analyzing related documents such as internal reports, promotional materials, and relevant operational records.

Data from interviews, observations, and documentation were analyzed using a thematic analysis approach. The steps in this analysis include:

(1) verbatim transcribing of the interviews,

(2) identifying and coding key themes within the data,

(3) grouping these codes into broader categories,

(4) identifying the primary themes that emerge from the data, and

(5) interpreting these themes to provide insights into the implementation of innovations, challenges, and sustainability impacts.

The data analysis process followed the interactive model developed by Miles and Huberman (1994), which comprises four key stages: data collection, data reduction, data presentation, and conclusion drawing/verification. During the data collection stage, information was gathered continuously through interviews and documents. Each interview was recorded with the respondent's permission and subsequently transcribed to support further analysis. In the data reduction stage, the focus shifted to selecting, simplifying, and transforming raw data into a more organized and meaningful format. Coding was used to identify key themes and categories emerging from the data, while irrelevant or repetitive information was eliminated to capture the essence. The reduced data was then presented through narratives to enhance interpretation. Conclusion drawing involves interpreting the presented data to identify meanings, patterns, and significant themes. The initial conclusions were verified to ensure their validity and reliability.

To ensure the credibility of the thematic findings, several verification strategies were applied. Theme development was reviewed through peer debriefing, where another qualitative researcher examined the coding structure and interpretations. Triangulation was also employed by comparing insights across different MSME sectors and data sources, helping to confirm the consistency and robustness of the themes.

This qualitative approach has several limitations. The findings are context-specific and cannot be statistically generalized beyond the sampled MSMEs. The analysis relies on participants' self-reported information, which may be subject to recall bias or social desirability bias. The researcher's interpretation also plays a central role in coding and theme development, which may introduce subjectivity despite efforts to ensure analytical rigor.

RESULTS AND DISCUSSION

Commitment of the Indonesian Government Towards the Circular Economy

The development of CE in Indonesia is a strategic initiative aimed at optimizing resource use, reducing waste, and promoting sustainable development. The Indonesian government is dedicated to implementing CE as an economic model that enhances resource efficiency, designs products for sustainability, and reintegrates production and consumption processes into the production cycle (UNDP Indonesia, 2022). This concept is incorporated into the 2020-2024 national medium-term development plan (RPJMN), with a particular emphasis on fostering a green economy. The government aims to strengthen economic resilience and growth by enhancing MSME competitiveness through accelerated adoption of new and renewable energy (GPQI, 2023).

The government has established ten principles for companies to adopt in order to implement CE practices. These principles emphasize the use of renewable energy, recyclable materials, long-term maintenance plans for products, and the recycling of waste and by-products as secondary raw resources (GPQI, 2023). Initiatives supporting these principles include the creation of a national action plan for the CE and the integration of CE strategies into the upcoming RPJMN 2025-2029 (Shifting Paradigms, 2020).

The implementation of CE in Indonesia is projected to boost GDP by 2.3 to 2.5 per cent by 2030, reduce CO_2 emissions by 126 million tons, create an additional 4.4 million jobs, and significantly lower household expenditures (Shifting Paradigms, 2020). The economic benefits include IDR 431.9 billion (approximately USD 30 million) in savings on operating costs, job opportunities for 14,270 workers, and emission reductions exceeding 1.4 million tons of carbon dioxide equivalent (CO_2e) (UNDP Indonesia, 2022). CE implementation focuses on food and beverage, textiles, construction, wholesale and retail trade, and electronics. These sectors could contribute to a GDP increase of IDR 593-638 trillion by 2030, generate annual household savings of nearly 9 per cent of the budget, and create 4.4 million jobs, with 75 per cent of these opportunities available for women (Shifting Paradigms, 2020; UNDP Indonesia, 2022)

The government, in collaboration with UNDP and the Danish government, has launched a book titled "*The future is circular: Concrete steps for circular economic initiatives in Indonesia*." This book serves as the first step in crafting a circular economic policy roadmap for Indonesia. Overall, the development of CE in Indonesia represents a comprehensive effort to transform the country's economic model into one that is more sustainable, efficient, and environmentally friendly. Key elements of this initiative include the government's commitment, its incorporation into national development plans, and a focus on various sectors (UNDP Indonesia, 2022). CE will play a significant role in helping Indonesia achieve its nationally determined contribution (NDC). Indonesia aims to reduce greenhouse gas emissions by 29% by 2030, with the potential to raise this target to 41% through international cooperation.

The concept of low-carbon development has been mainstreamed in the RPJMN 2020-2024 and the roadmap for achieving Indonesia's 2030 NDC. Both documents prioritize five sectors: sustainable energy development, integrated waste management, green industry development, sustainable land restoration, and the inventory and rehabilitation of coastal and marine ecosystems. From 2010 to 2019, 895 companies received green industry awards. Additionally, 1,707 industries achieved blue and gold certifications in the company performance rating program for environmental management. These efforts contributed to a reduction of approximately 93.83 million tons of greenhouse gases and 50.59 million tons of pollutants. The government has implemented strategic programs, including the development of B30 biofuel. Additionally, there have been advancements in converting waste into alternative fuels, notably through refuse derived fuel.

Table 1. Summary of 20 MSMEs studied by product, type of innovation, and CE practice

No	Product	Type of innovation	CE practice
1	Batik	Product innovation	Introducing eco-friendly product variations using natural dyes
2	Batik	Process innovation	Improving production process by treating liquid waste to reduce pollution
3	Batik craft	Product innovation	Creating new value-added products from batik waste materials
4	Ecoprint	Product innovation	Offering environmentally friendly products using natural dyes and plant materials
5	Ecoprint	Product innovation	Offering environmentally friendly products using natural dyes and plant materials
6	Ecoprint	Product + process innovation	Combining eco-friendly production with transformation of waste into new products.
7	Tofu	Process innovation	Supplying liquid waste to public disposal channels for biogas, a renewable energy production
8	Coconut husk products	Product innovation	Developing new products using coconut husk waste as the main input material
9	Coconut husk products	Product innovation	Developing new products using coconut husk waste as the main input material
10	Coffee shop	Product innovation	Sourcing only from suppliers practicing organic agriculture
11	Catering	Organizational/process innovation	Natural dyes, supplying organic waste to neighboring farmers for composting
12	Catering	Organizational/process innovation	Natural dyes, supplying organic waste to neighboring farmers as livestock feed
13	Used tire repurposing	Product innovation	Creating new value-added products from used tires
14	Used tire repurposing	Product innovation	Creating new value-added products from used tires
15	Waste collector	Process innovation	Improving waste-sorting processes to increase material recovery and recyclability
16	Garment	Organizational/process innovation	Supplying textile offcuts to other artisans as materials for craft-making
17	Bakery	Organizational/process innovation	Supplying eggshell waste to neighboring farmers to be processed into fertilizer
18	Fish processing	Product innovation	Processing fish sourced solely from organic cultivation systems
19	Snack production	Product innovation	Creating new snack products by repurposing food waste or by-products
20	Tourism village	Product innovation	Producing handicrafts from inorganic waste

Innovative Practices of Circular Economy Among Rural MSMEs in Banyumas District

Before moving to the thematic analysis, it is necessary to outline the profile of the MSMEs that constitute the empirical basis of this study. **Table 1** presents a structured summary of the 20 enterprises, detailing their product focus, the type of innovation implemented, and the corresponding CE practices. This descriptive overview provides a clear context for interpreting the subsequent results and establishes the analytical foundation for understanding how various forms of innovation support rural circularity in Banyumas District.

The innovative approaches employed by MSMEs in Banyumas District to implement CE practices include the use of environmentally friendly raw materials and auxiliaries, such as eco-print and natural dyes, the utilization of renewable energy sources, such as biogas, waste sorting for culinary businesses and waste banks, and waste repurposing. In addition to these well-established practices, MSMEs across different sectors also demonstrate a wider range of CE strategies, including organic sourcing, material circularity through inter-firm collaboration, and creative transformation of both organic and inorganic waste into new products.

One notable method is the use of eco-print and natural dyes as environmentally friendly raw materials. As an ecoprint artisan explained, "*Ecoprint is regarded as an eco-friendly practice because it consistently uses natural ingredients, including grasses, leaves, flowers, fruits, and twigs*." Eco-print transfers leaf and flower motifs onto fabrics, producing environmentally friendly waste, as the motifs and dyes are derived from natural materials (Annesha & Fajar, 2020; Flint, 2008; Rahmaningtyas et al., 2021). Natural dyes, extracted from plants, minerals, and animal-based sources, are biodegradable, non-toxic, and non-carcinogenic. They also protect against ultraviolet light (Cristea & Vilarem, 2006; Ibrahim et al., 2011; Prabhu & Teli, 2014; Sarkar, 2004; Sayem et al., 2021; Sun & Tang, 2011; Wang et al., 2024). In Banyumas District, natural dyes are used in eco-print and batik production. While all eco-print producers employ natural colours, most batik entrepreneurs still rely on synthetic dyes. This aligns with a batik entrepreneur's statement that, "*Batik typically uses chemical dyes, but we also develop batik products using natural dyes to differentiate ourselves from competitors. There is a segment of premium consumers who are concerned about and prefer natural-based products*." Synthetic dyes, although superior in color fastness and ease of application (Fobiri, 2022), pose significant environmental and health challenges. They often contain harmful chemicals such as sulfur, naphthol, and heavy metals, which can pollute water bodies and harm aquatic life if not properly disposed of (Garg & Chopra, 2022; Singha et al., 2021). Additionally, wastewater adversely affects soil, air, and plants, leading to various health issues for humans (Slama et al., 2021). Several batik and eco-print enterprises further innovate by repurposing textile waste into derivative products, demonstrating product-level circularity that expands their value chain. Waste repurposing enables the creation of accessories, decorative items, or small craft materials, thereby reducing solid waste and enhancing resource efficiency.

The use of natural dyes in batik production reflects a commitment to environmentally friendly practices while preserving a centuries-old tradition. Derived from plants, minerals, and animals, these dyes produce a wide range of colors. They offer several advantages over synthetic dyes, especially concerning their environmental impact and health benefits. Common examples of natural dyes used in batik and

eco-print production include Indigofera tinctoria, mahogany bark, Ceriops tagal, mangosteen rind, teak leaves, and turmeric. The natural dyeing process involves specific steps that differ from those used for synthetic dyes, as natural materials require more time and precision.

Beyond textiles, natural dyes are gaining popularity in culinary products and local crafts. Dyes derived from turmeric, pandan leaves, mangosteen peel, and other plants are used as alternatives to synthetic dyes, offering added health and product-safety benefits. The use of environmentally friendly raw materials not only reduces negative environmental impacts but also improves the market appeal of these products, both locally and internationally. MSMEs in food-related sectors also demonstrate circular practices. For example, coffee producers source beans exclusively from suppliers practicing organic agriculture, while fish-processing enterprises rely solely on organically farmed fish. These practices represent product innovations linked to sustainable sourcing. Meanwhile, snack-production MSMEs repurpose food waste into new snack products, thereby extending the utility of by-products that would otherwise be discarded.

The community in Banyumas District has begun to embrace renewable energy solutions. One of the key innovations is the use of biogas derived from livestock waste and tofu industry by-products. Biogas not only helps to reduce greenhouse gas emissions but also provides an alternative energy source that can replace fossil fuels. In tofu MSMEs, liquid waste is channeled to public disposal systems designed for biogas production, illustrating how process innovation can convert waste streams into renewable energy. Biogas not only helps to reduce greenhouse gas emissions but also provides an alternative energy source that can replace fossil fuels. Additionally, micro-hydro power plants are being harnessed in areas with rivers, such as Kalipondok hamlet in Karangtengah village, Cilongok District. These micro-hydro systems offer a sustainable, low-cost renewable energy source, supporting daily activities while reducing reliance on conventional electricity.

In the culinary sector, innovation is being introduced through effective waste sorting. Organic waste is separated for use as livestock feed or compost fertilizer. This practice is strengthened through collaboration with neighboring farmers, who routinely collect organic waste from catering and bakery MSMEs for composting or for feeding livestock such as goatsas described by one informant. "*In our village, mutual support is part of everyday life, so I separate organic waste, and my neighbors freely take it to use as fertilizer or as feed for their goats*." These arrangements illustrate organizational and process innovation rooted in local community embeddedness. In contrast, inorganic waste is processed at waste banks, facilitating organized waste management and generating economic value from sorted materials. Waste collectors further support CE by sorting mixed waste before sending recyclable materials to recycling facilities, enhancing material recovery at the district level. Culinary MSMEs also utilize food waste as animal feed, fostering a mutually beneficial cycle between the culinary industry and livestock farming. This strategy not only reduces waste volume but also offers economic benefits by lowering feed and fertilizer costs. In Banyumas District, there is no final disposal of waste because all waste has been processed through waste banks and integrated waste management sites.

Waste repurposing is another innovation. Coconut waste is transformed into coconut bristle, coconut fiber, and cocopeat, which are derived from processing coconut waste. This waste is transformed into various value-added products, including brooms, mats, planting media, and furniture. Coconut shells are converted into charcoal, briquettes, activated carbon, handicrafts, and even cosmetics such as soap and scrubs. Coconut-husk MSMEs in this study demonstrate product innovation by using coconut husk waste as their primary raw material, highlighting how agricultural by-products can support new rural industries. A producer highlighted local resource abundance, saying, "*Coconut husks are abundant in rural areas because people typically consume only the water and flesh… their use is still largely limited to brooms or doormats. But international markets prefer natural-based products, giving coconut-husk crafts strong export potential*." Used tires are also creatively processed into spare parts, furniture, sandals, and ropes. Some are recycled into rubber powder for asphalt or sports mats, while others undergo pyrolysis to produce alternative fuels (Alfansuri & Kurniawan, 2023). Yet many small-scale producers emphasize that only older nylon-thread tires are suitable for these crafts; modern radial tires reinforced with steel wires hinder production, illustrating technological and material constraints that affect CE practice viability. Textile MSMEs also engage in circular practices by supplying garment off-cuts to other artisans, enabling material circulation within local craft networks. Similarly, tourism-village groups transform inorganic waste such as plastic bottles and packaging into craft products for visitors, demonstrating community-led CE innovation in rural tourism.

Taken together, these practices show how rural MSMEs in Banyumas creatively apply CE principles by leveraging local resources and waste materials. Compared with studies in developed countries (e.g., Tura et al., 2019), the Banyumas case highlights grassroots innovations driven less by advanced technology and more by resource constraints and local creativity. Kirchherr et al. (2018) identify regulatory pressure, market demand, and cost savings as the main drivers of CE adoption in SMEs. Case evidence from Finland's textile sector shows that CE enhances efficiency, lowers costs, and strengthens brand image, though success relies on adaptability to market and technology shifts (Tura et al., 2019). Other studies confirm that CE reduces waste and optimizes resources (Lieder & Rashid, 2016), improves economic performance through cost savings and efficiency (Murray et al., 2017), and fosters resilience to market fluctuations. Beyond economic gains, CE also generates social benefits, including job creation in recycling and repair, and stronger community well-being (Stahel, 2016).

Challenges Facing MSMEs in Implementing the Circular Economy in Banyumas District

Innovative practices in batik and eco-print businesses, such as the use of natural dyes, face several challenges despite their advantages. Key issues include raw material scarcity, unstable colors, and high production costs. Certain dye plants are seasonal or sourced from distant areas, requiring precise coordination between fabric preparation and leaf delivery.

Moreover, natural dyes are often less resistant to sunlight and washing compared to synthetic dyes, making mordanting and fixation crucial for durability. The dyeing process is also more time-intensive and costly due to the repeated extraction and application steps.

Market demand also constrains eco-friendly textiles. Local purchasing power is limited, forcing producers to sell mainly in Jakarta-Bogor-Depok-Tangerang-Bekasi (Jabodetabek), where consumers can afford higher prices as noted by one of the artisans. "*Natural dyes are much more expensive than chemical dyes, which makes ecoprint products pricier … many consumers still do not understand the differences between chemical and natural dyes … this is why consumer education is so important*." Similarly, eco-print entrepreneurs report that the prices of certain natural dyes are very high, leading to selling prices that far exceed those of fabrics with synthetic dyes. This aligns with findings that green products often face market acceptance barriers unless supported by consumer awareness and stronger purchasing power (Kirchherr et al., 2018).

In renewable energy, biogas installations in Kalisari village have shown mixed results, with only three of six units functioning effectively. Problems arise from inconsistent tofu waste quality, inappropriate digester design, and irregular maintenance. Prior research confirms that feedstock variability and design mismatch can destabilize methane production (Mir et al., 2016; Schnürer, 2016). Inconsistent management and maintenance also affect the installation's performance. Biogas digesters require regular monitoring of temperature and pH to ensure optimal microbial activity. According to Ashur and Bengharbia (2015), temperature and pH variability can reduce gas production by up to 30% in anaerobic digesters. The lack of training further undermines sustainability, as Chodkowska-Miszczuk (2022) highlights the role of user education.

Waste-based industries also face supply shortages. For example, tire craftsmen in Kebanaran struggle due to the dominance of radial tires, which are harder to process than bias tires. A used-tire craftsman lamented,

> There used to be many artisans who crafted products from used tires, but most have closed… modern tires contain steel wires which are very difficult to cut using simple tools … what was once a thriving craft sector has disappeared because the materials themselves have changed.

Alternatives such as recycling into asphalt, pyrolysis for fuel, or construction use have been suggested (Alfansuri & Kurniawan, 2023; Nastain & Maryoto, 2018), but local adoption remains limited. Overall, the challenges in Banyumas resemble global barriers to CE adoption — financial constraints, lack of knowledge and awareness, and regulatory challenges, limited access to technology and infrastructure, and market uncertainty (Asfahani et al., 2023; Binek & Al-Muhannadi, 2020; Bocken et al., 2016; García-Quevedo et al., 2020; Kirchherr et al., 2018), but are magnified by local factors such as seasonal raw material supply and limited consumer demand. This underscores the importance of tailored policy support and capacity building for rural MSMEs.

Opportunities for Rural MSMEs in Banyumas District in Implementing Circular Economy

Rural Banyumas offers significant opportunities to advance CE due to its abundant natural resources and creative local industries. Leaves, flowers, and tree bark provide eco-print and dyeing materials, while coconut husks—often discarded—can be processed into high-value handicrafts, planting media, and bioenergy. Using waste as raw material can simultaneously reduce costs and generate new income streams. Creative MSMEs transform agricultural by-products into eco-friendly bags, crafts, and organic fertilizers, appealing to environmentally conscious consumers in both domestic and international markets. This reflects Rizos et al. (2016), who note that SMEs often leverage local resources and networks to innovate despite limited capital.

Waste substitution also enhances competitiveness. For instance, artisans who replace synthetic inputs with coconut husks or tire rubber achieve cost savings while offering greener products. Lower production costs improve profit margins and expand access to eco-sensitive markets. This aligns with Bocken et al. (2016), who emphasize the potential of sustainable product markets. Collaboration presents another opportunity. In a CE ecosystem, one enterprise's waste becomes another's resource—for example, coconut processors selling husks to handicraft producers. Such partnerships foster innovation, reduce waste, and create new business models. These findings align with international evidence that collaboration strengthens SMEs' capacity for CE (Bocken et al., 2016; Rizos et al., 2016). Taken together, Banyumas MSMEs demonstrate how rural areas can convert resource abundance and community collaboration into CE opportunities. While their innovations differ from high-tech CE models in developed countries, they highlight grassroots strategies with strong potential for replication in similar rural contexts.

Based on the key findings presented earlier, **Table 2** maps the ways in which local resource endowments and enterprise-level innovations operate as interconnected drivers in the development of the CE ecosystem in Banyumas District.

The patterns observed in Banyumas align closely with evidence from rural and resource-constrained regions across the Global South, where CE adoption is typically shaped by structural limitations, locally embedded knowledge systems, and socially driven modes of organising production. In Sub-Saharan Africa, for instance, CE uptake is frequently propelled by community-based initiatives—such as youth and women's collectives and regional alliances like the African circular economy network—yet constrained by persistent deficits in political commitment, financing, and public awareness (Debrah et al., 2022; Khan & Ali Mihaisi, 2023; Koech et al., 2023; Zhang et al., 2025). Similar to Banyumas, these contexts illustrate how CE practices often emerge informally, even when SMEs do not explicitly label their activities as "circular" (Adesua-Lincoln, 2025), and how infrastructural and regulatory gaps continue to limit more transformative adoption (Zuofa et al., 2023).

In Southeast Asia, CE transitions remain uneven. While Vietnam demonstrates relatively advanced progress enabled by organizational leadership and innovation capabilities (Chowdhury et al., 2022; Herrador & Van, 2024), many SMEs—

Table 2. Rural CE ecosystem in Banyumas District: Local resources, innovation, and circular practices

Component	Description	Examples from Banyumas MSMEs
Local inputs	Abundant local natural resources and waste streams are used as raw materials for innovation.	• Leaves, flowers, bark for eco-print and natural dyes • Coconut husks, shells, and fibers • Tofu liquid waste for biogas Agricultural by-products • Waste tires
Types of innovation	Innovations applied by MSMEs to transform resources and waste into value-added products.	**Product Innovation:** Eco-print textiles, coconut husk crafts, tire-based crafts, natural dyed batik, food waste–based snacks. **Process Innovation:** Waste sorting (culinary), wastewater treatment (batik), waste bank sorting, biogas production (tofu). **Organizational Innovation:** Partnerships with farmers for composting, exchange of offcuts among artisans.
CE practices	CE principles implemented in production and consumption	• Waste repurposing (coconut, tires, food waste) • Waste-to-energy (biogas) • Renewable materials (natural dyes) • Resource loops (waste banks, offcuts exchange) • Organic waste for compost and livestock feed
Resource loops	How waste becomes input for other enterprises, creating circularity	• Tofu waste → biogas units • Catering organic waste → animal feed/fertilizer • Textile offcuts → handicraft artisans • Coconut waste → fiber, charcoal, briquettes, crafts • Mixed waste → waste banks
Actors involved	MSMEs, local community groups, farmers, artisans, waste banks, tourism village managers.	• Eco-print producers • Batik artisans • Coconut husk processors • Culinary MSMEs, tofu producers • Waste collectors and waste banks • Tire artisans
Value creation	Environmental, economic, and social value generated	• Reduced pollution (batik wastewater treatment) • New products and markets (eco-print, coconut fibers) • Lower production cost (waste substitution) • Job creation (recycling, craft-making)
Constraints	Local limitations that hinder CE implementation	• Seasonal supply of dye plants • Unstable color quality • Limited local purchasing power • Design mismatch in biogas units maintenance problems • Shift from nylon-based to radial tires

including women-led enterprises in the Philippines—continue to operate within linear production logics due to limited ecodesign capacity, weak partnerships, and insufficient access to renewable inputs (Katigbak & Villaruel, 2023). Evidence from Thailand and Malaysia further highlights the importance of institutional facilitation, with community-level waste-reutilization initiatives demonstrating significant CE outcomes (Thongplew et al., 2022), even as SMEs struggle with high costs, limited market demand, regulatory pressures, and low awareness (Indiran et al., 2025).

South Asian studies also parallel the Banyumas context. Nepal's fragmented and partially operational CE elements indicate that CE adoption in developing economies remains contingent on targeted policy reform and integration within broader socio-economic frameworks (Melles et al., 2025). In India, CE uptake is shaped by technological readiness and capability constraints, with Industry 4.0 technologies presenting both enablers and barriers for SMEs (Despoudi et al., 2025; Nudurupati et al., 2022), and with financial, informational, and infrastructural deficits emerging as systemic obstacles (Kumar et al., 2025; Mishra et al., 2025).

Comparable dynamics are present in Latin America. Cases from Mexico, Chile, and Spain underscore that CE implementation success depends on alignment with local institutional and market conditions, and that misalignment exacerbates implementation barriers (Cantú et al., 2021; Gallego-Schmid et al., 2025; Ormazabal et al., 2018; Villegas Pinuer et al., 2021). Spanish and Chilean SMEs, like those in Banyumas, often prioritize cost savings and regulatory compliance over broader CE transformation (Pinuer et al., 2024), whereas Colombian evidence illustrates that eco-innovation can produce measurable environmental and socio-economic gains even within structurally constrained settings (Tegethoff et al., 2025).

Taken together, this cross-regional evidence demonstrates that the CE practices of Banyumas MSMEs—characterized by low-tech innovation, material circularity grounded in locally abundant resources, and community-embedded cooperation—fit within a broader developing-country pattern in which CE emerges through necessity-driven creativity rather than through capital-intensive technological upgrading. At the same time, the comparative literature reinforces that structural constraints observed in Banyumas—including limited financing, weak market incentives, technological barriers, and modest consumer awareness—are not unique but instead constitute recurrent features of CE transitions in rural and emerging-economy contexts.

CONCLUSIONS

This research aims to identify various innovative practices in the implementation of the CE by rural MSMEs in Banyumas District, Central Java. The study revealed practices such as the use of environmentally friendly raw materials, renewable energy, waste sorting, and reuse. These practices are motivated by cost efficiency, market demand, and environmental concerns, though constrained by the limited availability of natural dyes, high production costs, consumer unawareness, and maintenance difficulties with renewable energy systems. The findings contribute to the field by highlighting the unique rural MSME context in Indonesia, which is often overlooked in CE studies that focus on urban or industrial clusters. This research demonstrates that rural MSMEs can act as local sustainability drivers but face distinct challenges, including resource scarcity, weak infrastructure, and limited consumer awareness.

Government support remains essential. Key enablers include financial incentives and green financing, infrastructure for waste and renewable energy, training and capacity building, and multi-stakeholder collaboration. To make these implications more actionable, the study recommends:

(1) establishing village-level CE training centers to strengthen technical and managerial capabilities,

(2) providing targeted fiscal incentives and blended financing schemes for MSMEs adopting CE models, and

(3) developing community-based CE clusters that connect MSMEs, farmers, waste banks, and artisan groups to enhance material circulation and local value creation.

These recommendations align with Indonesia's national circular economy roadmap and its sustainability commitments, particularly SDG 6 (clean water and sanitation), SDG 7 (affordable and clean energy), SDG 8 (decent work and economic growth), and SDG 12 (responsible consumption and production). Incorporating gender-inclusive training and promoting women-led MSMEs are also important for enhancing equitable participation within rural CE ecosystems.

Further studies on cross-sector collaborative platforms that integrate MSMEs, academia, local government, and civil society are needed to scale innovation and enhance rural competitiveness. Future work should also deepen theoretical engagement by assessing how grassroots CE practices align with or challenge existing frameworks such as industrial ecology, systems thinking, and sustainable development theory.

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REFERENCES

Adesua-Lincoln, A. (2025). Challenges to environmental sustainability and circular economy practices of Nigerian small and medium enterprises. *Journal of Sustainable Business, 10*(1), Article 6. https://doi.org/10.1186/s40991-025-00110-9

Alfansuri, A., & Kurniawan, I. (2023). Performa mesin dengan menggunakan bahan bakar minyak plastik hasil teknologi pirolisis [Engine performance using plastic fuel oil from pyrolysis technology]. *E-Journal Polbeng, 13*(1), Article 64. https://doi.org/10.35314/ip.v13i1.3250

Annesha, B., & Fajar, C. (2020). Perancangan tekstil tenun gedog menggunakan teknik eco-print dengan inspirasi batik tuban [Gedog woven textile design using eco-print technique with tuban batik inspiration]. *E-Proceeding of Art & Design, 7*(2), 3957-3976.

Asfahani, Z., Sopha, B. M., & Wibisono, M. A. (2023). Barriers to circular economy transition in small and medium-sized businesses: A systematic review. In *Proceedings of the 2023 IEEE International Conference on Industrial Engineering and Engineering Management* (pp. 470-474). IEEE. https://doi.org/10.1109/IEEM58616.2023.10406486

Ashur, M., & Bengharbia, I. (2015). Effect of temperature and PH on biogas production from organic fraction–MSW. *Solar Energy and Sustainable Development Journal, 4*(1), 22-28. https://doi.org/10.51646/jsesd.v4i1.80

Berlemann, M., & Jahn, V. (2016). Regional importance of mittelstand firms and innovation performance. *Regional Studies, 50*(11), 1819-1833. https://doi.org/10.1080/00343404.2015.1058923

Binek, D., & Al-Muhannadi, K. (2020). Small and medium-sized enterprises within the circular economy: Challenges and opportunities. *Hungarian Agricultural Engineering, 37*, 5-13. https://doi.org/10.17676/HAE.2020.37.5

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering, 33*(5), 308-320. https://doi.org/10.1080/21681015.2016.1172124

Cantú, A., Aguiñaga, E., & Scheel, C. (2021). Learning from failure and success: The challenges for circular economy implementation in SMEs in an emerging economy. *Sustainability, 13*(3), Article 1529. https://doi.org/10.3390/su13031529

Chodkowska-Miszczuk, J. (2022). A new narrative for sustainability: Exploring biogas plants as 'first movers' in raising energy awareness. *Australian Journal of Environmental Education, 38*(2), 152-167. https://doi.org/10.1017/aee.2021.17

Chowdhury, S., Dey, P. K., Rodríguez-Espíndola, O., Parkes, G., Tuyet, N. T. A., Long, D. D., & Ha, T. P. (2022). Impact of organisational factors on the circular economy practices and sustainable performance of small and medium-sized enterprises in Vietnam. *Journal of Business Research, 147*, 362-378. https://doi.org/10.1016/j.jbusres.2022.03.077

Cristea, D., & Vilarem, G. (2006). Improving light fastness of natural dyes on cotton yarn. *Dyes and Pigments, 70*(3), 238-245. https://doi.org/10.1016/j.dyepig.2005.03.006

Debrah, J. K., Teye, G. K., & Dinis, M. A. P. (2022). Barriers and challenges to Waste Management hindering the circular economy in sub-Saharan Africa. *Urban Science, 6*(3), Article 57. https://doi.org/10.3390/urbansci6030057

Despoudi, S., Sivarajah, U., Spanaki, K., Charles, V., & Durai, V. K. (2025). Industry 4.0 and circular economy for emerging markets: Evidence from small and medium-sized enterprises (SMEs) in the Indian food sector. *Annals of Operations Research, 350*(2), 453-491. https://doi.org/10.1007/s10479-023-05404-4

Flint, I. (2008). *Eco colour: Botanical dyes for beautiful textiles*. Murdoch Books Pty Limited.

Fobiri, G. K. (2022). Synthetic dye application in textiles: A review on the efficacies and toxicities involved. *Textile & Leather Review, 5*, 180-198. https://doi.org/10.31881/TLR.2022.22

Fortunato, M. W.-P. (2014). Supporting rural entrepreneurship: A review of conceptual developments from research to practice. *Community Development, 45*(4), 387-408. https://doi.org/10.1080/15575330.2014.935795

Frosch, R. A., & Gallopoulos, N. E. (1989). Strategies for manufacturing. *Scientific American, 261*(3), 144-152. https://doi.org/10.1038/scientificamerican0989-144

Gallego-Schmid, A., Vásquez-Ibarra, L., Guerrero, A. B., Henninger, C. E., & Rebolledo-Leiva, R. (2025). Circular economy in a recently transitioned high-income country in Latin America and the Caribbean: Barriers, drivers, strengths, opportunities, key stakeholders and priorities in Chile. *Journal of Cleaner Production, 486*, Article 144429. https://doi.org/10.1016/j.jclepro.2024.144429

García-Quevedo, J., Jové-Llopis, E., & Martínez-Ros, E. (2020). Barriers to the circular economy in European small and medium-sized firms. *Business Strategy and the Environment, 29*(6), 2450-2464. https://doi.org/10.1002/bse.2513

Garg, A., & Chopra, L. (2022). Dye waste: A significant environmental hazard. *Materials Today: Proceedings, 48*, 1310-1315. https://doi.org/10.1016/j.matpr.2021.09.003

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

GPQI. (2023). Going circular: The development of Indonesia's circular economy. *Global Project Quality Infrastructure*. https://www.gpqi.org/news_en-details/going-circular-the-development-of-indonesia-s-circular-economy.html

Harangozó, G., & Zilahy, G. (2015). Cooperation between business and non-governmental organizations to promote sustainable development. *Journal of Cleaner Production, 89*, 18-31. https://doi.org/10.1016/j.jclepro.2014.10.092

Hartley, K., Roosendaal, J., & Kirchherr, J. (2022). Barriers to the circular economy: The case of the Dutch technical and interior textiles industries. *Journal of Industrial Ecology, 26*(2), 477-490. https://doi.org/10.1111/jiec.13196

Herrador, M., & Van, M. L. (2024). Circular economy strategies in the ASEAN region: A comparative study. *Science of The Total Environment, 908*, Article 168280. https://doi.org/10.1016/j.scitotenv.2023.168280

Hossain, M. U., Ng, S. T., Antwi-Afari, P., & Amor, B. (2020). Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction. *Renewable and Sustainable Energy Reviews, 130*, Article 109948. https://doi.org/10.1016/j.rser.2020.109948

Ibrahim, N. A., El-Zairy, W. M., El-Zairy, M. R., Eid, B. M., & Ghazal, H. A. (2011). A smart approach for enhancing dyeing and functional finishing properties of cotton cellulose/polyamide-6 fabric blend. *Carbohydrate Polymers, 83*(3), 1068-1074. https://doi.org/10.1016/j.carbpol.2010.08.053

Indiran, L., Abdullah, M., Raj, J., & Hassan, M. S. (2025). The challenges of sustainability practices among SMEs: Interview with CEOs in Malaysia. *IOP Conference Series: Earth and Environmental Science, 1488*, Article 012038. https://doi.org/10.1088/1755-1315/1488/1/012038

Katigbak, J. J., & Villaruel, J. J. (2023). Assessing the adoption of circular economy among women-led MSMEs in Metro Manila: A pilot study. *PIDS*. https://doi.org/10.62986/dp2023.30

Khan, R., & Ali Mihaisi, S. M. K. (2023). Promoting circular economy model through SMEs' growth: A focus on African nations. *Journal of Production, Operations Management and Economics, 3*(6), 40-52. https://doi.org/10.55529/jpome.36.40.52

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: Evidence from the European Union (EU). *Ecological Economics, 150*, 264-272. https://doi.org/10.1016/j.ecolecon.2018.04.028

Koech, M. K., Munene, K. J., Kinoti, M. K., & Situma, D. K. (2023). Circular economy policies and innovations in africa: Pillars for achieving sustainable development BT. In S. K. Ghosh, & S. K. Ghosh (Eds.), *Circular economy adoption: Catalysing decarbonisation through policy instruments* (pp. 99-130). Springer. https://doi.org/10.1007/978-981-99-4803-1_4

Korsgaard, S., Ferguson, R., & Gaddefors, J. (2015a). The best of both worlds: How rural entrepreneurs use placial embeddedness and strategic networks to create opportunities. *Entrepreneurship & Regional Development, 27*(9-10), 574-598. https://doi.org/10.1080/08985626.2015.1085100

Korsgaard, S., Müller, S., & Tanvig, H. W. (2015b). Rural entrepreneurship or entrepreneurship in the rural - between place and space. *International Journal of Entrepreneurial Behavior & Research, 21*(1), 5-26. https://doi.org/10.1108/IJEBR-11-2013-0205

Kranzusch, P., May-Strobl, E., & Levering, B. (2017). Innovation und Wachstum als Herausforderung für den Mittelstand: Update der Unternehmersicht 2017 [Innovation and growth as a challenge for SMEs: Update of the entrepreneurial perspective 2017]. *IfM-Materialien, 260*.

Kumar, P. S., & Suganya, S. (2019). Systems and models for circular economy. In *Circular economy in textiles and apparel* (pp. 169-181). Elsevier. https://doi.org/10.1016/B978-0-08-102630-4.00008-X

Kumar, S., Kumar, R., Phanden, R. K., & Rathi, R. (2025). Implementing circular economy practices in Indian SMEs: Analysis of challenges with case study. *International Journal of Advanced Operations Management, 16*(1), 35-59. https://doi.org/10.1504/IJAOM.2025.145197

Lang, R., Fink, M., & Kibler, E. (2014). Understanding place-based entrepreneurship in rural Central Europe: A comparative institutional analysis. *International Small Business Journal: Researching Entrepreneurship, 32*(2), 204-227. https://doi.org/10.1177/0266242613488614

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production, 115*, 36-51. https://doi.org/10.1016/j.jclepro.2015.12.042

López-Morales, V., Ouzrout, Y., Manakitsirisuthi, T., & Bouras, A. (2015). MKMSIS: A multi-agent knowledge management system for industrial sustainability. In Y. Laalaoui, & N. Bouguila (Eds.), *Artificial intelligence applications in information and communication technologies. Studies in computational intelligence, vol 607* (pp. 195-213). Springer. https://doi.org/10.1007/978-3-319-19833-0_9

Meadows, D. H. (2008). *Thinking in systems: A primer*. Chelsea Green Publishing Company.

Melles, G., Gautam, S., & Shrestha, R. (2025). Towards a sustainable circular economy (SCE) for Nepal: Current realities and perspectives. *Challenges, 16*(3), Article 44. https://doi.org/10.3390/challe16030044

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. SAGE.

Mir, M. A., Hussain, A., & Verma, C. (2016). Design considerations and operational performance of anaerobic digester: A review. *Cogent Engineering, 3*(1), Article 1181696. https://doi.org/10.1080/23311916.2016.1181696

Mishra, S., Sahoo, D., & Mohapatra, S. (2025). Barriers to circular economy adoption in MSMEs: A WINGS analysis of challenges in developing economies. Circular Economy and *Sustainability, 5*, 4919-4944. https://doi.org/10.1007/s43615-025-00668-3

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

Nastain, N., & Maryoto, A. (2018). Tingkat ketahanan API batako ban bekas untuk material dinding bangunan [API resistance level of used tire bricks for building wall materials]. *Jurnal Teknik Sipil, 25*(2), Article 167. https://doi.org/10.5614/jts.2018.25.2.10

Nudurupati, S. S., Budhwar, P., Pappu, R. P., Chowdhury, S., Kondala, M., Chakraborty, A., & Ghosh, S. K. (2022). Transforming sustainability of Indian small and medium-sized enterprises through circular economy adoption. *Journal of Business Research, 149*, 250-269. https://doi.org/10.1016/j.jbusres.2022.05.036

Ogunsuji, Y. M., Amosu, O. R., Choubey, D., Abikoye, B. E., Kumar, P., & Umeorah, S. C. (2024). Sustainable procurement practices: Adoption of renewable energy sources and technologies through strategic procurement policies. W*orld Journal of Advanced Research and Reviews, 23*(2), 1410-1422. https://doi.org/10.30574/wjarr.2024.23.2.2443

Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., & Jaca, C. (2018). Circular economy in Spanish SMEs: Challenges and opportunities. *Journal of Cleaner Production, 185*, 157-167. https://doi.org/10.1016/j.jclepro.2018.03.031

Palombi, G., Schiaroli, V., Fraccascia, L., & Nonino, F. (2024). Identifying barriers and good practices for implementing circular economy principles in small and medium enterprises. *Business Strategy and the Environment, 33*(7), 6773-6794. https://doi.org/10.1002/bse.3835

Pinuer, F. V., Andreu, J. L., & Belbeze, P. L. (2024). Environmental sustainability and circular economy in SMEs: A qualitative approach from the Spanish experience. *International Journal of Entrepreneurship and Small Business, 51*(3), 404-431. https://doi.org/10.1504/IJESB.2024.136346

Prabhu, K. H., & Teli, M. D. (2014). Eco-dyeing using Tamarindus indica L. seed coat tannin as a natural mordant for textiles with antibacterial activity. *Journal of Saudi Chemical Society, 18*(6), 864-872. https://doi.org/10.1016/j.jscs.2011.10.014

Rahmaningtyas, W. D., Hendrawan, A., & Sigit, R. M. (2021). Pemanfaatan daun eceng gondok sebagai pewarna alami [Utilization of water hyacinth leaves as a natural dye]. *E-Proceeding of Art & Design, 8*(6), 3601-3615.

Ranta, V., Aarikka-Stenroos, L., & Mäkinen, S. J. (2018). Creating value in the circular economy: A structured multiple-case analysis of business models. *Journal of Cleaner Production, 201*, 988-1000. https://doi.org/10.1016/j.jclepro.2018.08.072

Rizos, V., Behrens, A., Van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. *Sustainability, 8*(11), Article 1212. https://doi.org/10.3390/su8111212

Sarkar, A. K. (2004). An evaluation of UV protection imparted by cotton fabrics dyed with natural colorants. *BMC Dermatology, 4*(1), Article 15. https://doi.org/10.1186/1471-5945-4-15

Sayem, A. N. M., Ahmed, F., Saha, P., & Talukder, B. (2021). A review on natural dyes: Raw materials, extraction process, and their properties. *Advance Research in Textile Engineering, 6*(1). https://doi.org/10.26420/advrestexteng.2021.1062

Schnürer, A. (2016). Biogas production: Microbiology and technology. In R. Hatti-Kaul, G. Mamo, & B. Mattiasson (Eds.), *Anaerobes in biotechnology* (pp. 195-234). Springer. https://doi.org/10.1007/10_2016_5

Shifting Paradigms. (2020). The economic, social, and environmental impact of the circular economy in Indonesia. *Shifting Paradigms*. https://www.shiftingparadigms.nl/projects/the-economic-social-and-environmental-impact-of-the-circular-economy-in-indonesia/

Singha, K., Pandit, P., Maity, S., & Sharma, S. R. (2021). Harmful environmental effects for textile chemical dyeing practice. In N. Ibrahim, & C. M. Hussain (Eds.), *Green chemistry for sustainable textiles* (pp. 153-164). Elsevier. https://doi.org/10.1016/B978-0-323-85204-3.00005-1

Slama, H. Ben, Chenari Bouket, A., Pourhassan, Z., Alenezi, F. N., Silini, A., Cherif-Silini, H., Oszako, T., Luptakova, L., Golińska, P., & Belbahri, L. (2021). Diversity of synthetic dyes from textile industries, discharge impacts and treatment methods. *Applied Sciences, 11*(14), Article 6255. https://doi.org/10.3390/app11146255

Stahel, W. R. (2016). The circular economy. *Nature, 531*(7595), 435-438. https://doi.org/10.1038/531435a

Sun, S.-S., & Tang, R.-C. (2011). Adsorption and UV protection properties of the extract from honeysuckle onto wool. *Industrial & Engineering Chemistry Research, 50*(8), 4217-4224. https://doi.org/10.1021/ie101505q

Tegethoff, T., Santa, R., Bucheli, J. M., Cabrera, B., & Scavarda, A. (2025). Sustainable development through eco-innovation: A focus on small and medium enterprises in Colombia. *PLoS ONE, 20*(1), Article e0316620. https://doi.org/10.1371/journal.pone.0316620

Teo, T. C., Zhang, A., Djuraeva, Z., & Ettibaev, A. (2023). Out of Uzbekistan: The barriers of adopting circular business practices in rural SMEs. *Journal of Human Resource and Sustainability Studies, 11*(2), 356-380. https://doi.org/10.4236/jhrss.2023.112021

Thongplew, N., Onwong, J., Kotlakome, R., & Suttipanta, N. (2022). Approaching circular economy in an emerging economy: A solid-waste reutilization initiative in a small fresh market in Thailand. *Sustainability: Science, Practice and Policy, 18*(1), 665-678. https://doi.org/10.1080/15487733.2022.2110677

Tura, N., Hanski, J., Ahola, T., Ståhle, M., Piiparinen, S., & Valkokari, P. (2019). Unlocking circular business: A framework of barriers and drivers. *Journal of Cleaner Production, 212*, 90-98. https://doi.org/10.1016/j.jclepro.2018.11.202

UNDP Indonesia. (2022). The future is circular: Policies and practices for a sustainable Indonesia. *UNDP*. https://www.undp.org/indonesia/press-releases/undp-bappenas-launch-book-circular-economy

Uvarova, I., Atstaja, D., & Vitola, A. (2019). Circular economy driven innovations within business models of rural SMEs. *SOCIETY. INTEGRATION. EDUCATION. Proceedings of the International Scientific Conference, 6*, Article 520. https://doi.org/10.17770/sie2019vol6.3951

Villegas Pinuer, F. J., Llonch Andreu, J., Belbeze, P. L., & Valenzuela-Fernández, L. (2021). Waste management. The disconnection between normative and SMEs reality. *Sustainability, 13*(4), Article 1787. https://doi.org/10.3390/su13041787

Wang, L., Hu, H., Du, Y., Mi, X., Zhu, Q., Chen, Q., Gui, Z., Zhang, B., & Yu, Z. (2024). Eco-friendly and sustainable application of gardenia yellow extraction as natural dye source for dyeing and bio-functional finishing of cotton fabric. *Cellulose, 31*(4), 2583-2601. https://doi.org/10.1007/s10570-023-05724-5

Yerznkyan, B. H., & Fontana, K. A. (2023). Exploring the barriers to a circular economy (small and medium enterprises). *Market Economy Problems, 2*, 6-24. https://doi.org/10.33051/2500-2325-2023-2-06-24

Zhang, J., Adu Sarfo, P., Adjorlolo, G., Appiah, A., Nyantakyi, G., Bonzo, J. K., & Alam, S. (2025). Leveraging knowledge sharing for circular economy practices in small and medium-sized enterprises (SMEs): A pathway to achieving SDGs in sub-Saharan Africa. *Journal of Enterprise Information Management*. https://doi.org/10.1108/JEIM-03-2025-0188

Zuofa, T., Ochieng, E. G., & Ode-Ichakpa, I. (2023). An evaluation of determinants influencing the adoption of circular economy principles in Nigerian construction SMEs. *Building Research & Information, 51*(1), 69-84. https://doi.org/10.1080/09613218.2022.2142496