WORKING PAPER

CIRCULAR ECONOMY-BASED MSME BUSINESS MODEL DEVELOPMENT: PILOTING IN SEVERAL BI'S REPRESENTATIVE OFFICE

Donni Fajar Anugrah, Freddy Firmansyah, Melyanna Nur Ainni, Honesty Saffira Putri, Mohammad Marza Naufal, Hilya Jannatul Imron, Owen Alberto Liem, Arnita Rishanty, Ratna Oktriyani, Rudy Marhastari, Dila Safitri

2025

CIRCULAR ECONOMY-BASED MSME BUSINESS MODEL DEVELOPMENT: PILOTING IN SEVERAL BI'S REPRESENTATIVE OFFICE

Donni Fajar Anugrah, Freddy Firmansyah, Melyanna Nur Ainni, Honesty Saffira Putri, Mohammad Marza Naufal, Hilya Jannatul Imron, Owen Alberto Liem, Arnita Rishanty, Ratna Oktriyani, Rudy Marhastari

Abstract

This research aims to formulate a circular economy-based MSME business model through a pilot program at several Bank Indonesia Domestic Representative Offices. Using a mixed-methods approach, the study combines quantitative analysis, including Cost-Benefit Analysis (CBA), Social Benefit-Cost Ratio (SBCR), and an Input-Output model, with qualitative analysis through interviews, FGDs, and field observations. The results of the study show that the implementation of the circular economy by MSMEs provides significant economic and social benefits, including increased cost efficiency, increased value creation, reduced waste, and a positive contribution to labor absorption. The integration of social benefits into the feasibility analysis showed an increase in the SBCR ratio, reinforcing the argument that the circular economy plays a role in lowering environmental impact and improving local well-being. This study recommends strengthening supply chain partnerships, increasing access to green financing, advancing business digitalization, implementing quality certification, and developing cluster ecosystems as acceleration strategies.

1. Introduction

1.1 Background

Indonesia faces major challenges in waste management, which affect environmental pollution, increased greenhouse gas emissions, and economic pressure. In 2023, Indonesia will produce around 40.1 million tons of waste, dominated by food waste (38.94%), followed by plastic (19.22%) and wood or twigs (12.61%) (MoEF, 2023). Low community participation, limited facilities, and the lack of integration of the informal sector are the main obstacles in waste management (Salsabila et al., 2023). Meanwhile, population growth, urbanization, and industrial expansion continue to increase the volume of landfills, especially plastic waste (Hidayat et al., 2019). On the governance side, overlapping authority between central and regional governments hinders the enforcement of producer responsibility (Hardi et al., 2024). In addition, most landfills are still managed openly without adequate recycling systems, exacerbating the environmental crisis (Munawar et al., 2018).

In response to the challenges of sustainable waste management, the circular economy approach is gaining attention because it can integrate cross-sector policies and encourage collaboration among stakeholders to build long-term urban resilience (Subekti, 2023). This approach not only creates economic value by converting waste into new, competitive commodities but also supports green economic growth through innovation and sustainable job creation (Amalia & Lathifah, 2024). Turlakova (2023) emphasizes that the circular economy transforms conventional business models by preserving the value of products and materials through reuse, recycling, and repair practices, including strategies such as industrial symbiosis to improve resource efficiency and innovation.

In the financial sector, the circular economy can provide opportunities such as loan diversification, increased profits from recycling businesses, and a positive reputation for financial institutions that support green investment (Ozili, 2021). According to Zlotnik (2021), integrating the circular economy into corporate strategies is important for increasing companies' post-pandemic competitiveness and resilience, including through environmentally friendly product design and the implementation of closed supply chains. The implementation of the circular economy also extends to agriculture, fashion, creative industries, and household sectors, demonstrating a wide and diverse scope.

One circular economy practice is the use of Black Soldier Fly (BSF), or Hermetia illucens, which has an extraordinary ability to convert organic waste into high-value products. BSF larvae not only provide an efficient biological solution for waste treatment but also produce protein-rich biomass that can be used as feed for livestock, fish, and poultry, thereby reducing reliance on high-carbon feed materials such as fishmeal and soybeans (Odongo et al., 2024). Waste utilization is also implemented through the PESONA SUBANG program, which transforms pineapple leaf waste into high-value eco-fashion products while empowering local communities through training and job creation (Fatmawati et al., 2024). The aesthetic value and design innovation have also received attention, as shown by Fasza (2017) through the use of traditional Sashiko embroidery and natural dyes in pineapple fibers to develop ethnic fashion.

In the creative industry, plastic waste is an innovative raw material for the manufacture of functional furniture. Global and national studies show that recycled plastics, such as HDPE and mixed waste, can be used to produce durable and weather-resistant outdoor furniture (Shiri et al., 2019; Bolong et al., 2024). In Indonesia, modular design initiatives using recycled plastics for public spaces

(Priandika et al., 2021) show great potential for reducing waste while supporting the growth of local creative industries.

Household waste, such as used cooking oil, also has great potential to be recycled into valuable products, such as aromatherapy candles and soaps, thus opening sustainable business opportunities while reducing environmental pollution. Community training in processing used cooking oil has been proven to increase environmental awareness and entrepreneurial skills (Irawan et al., 2024; Wijayanto et al., 2023). Formulation innovations, such as those reported by Pratisto et al. (2024) and Azme et al. (2023), have even resulted in soap and wax products with high market value and positive social impact, while Octarya et al. (2025) introduced eco-enzymes and lemongrass extracts to produce environmentally friendly antibacterial soaps.

In general, the circular economy is seen as a tool for inclusive economic development, with significant potential to reduce unemployment, promote gender equality, and reduce dependence on natural resources (Drakulevski & Boshkov, 2019). Zemanová (2023) also noted various advantages, such as cost efficiency, improved corporate image, and competitive advantage, although obstacles, including low awareness and a lack of regulation, remain major challenges. With the right business strategy and policy support, the circular economy can provide broad economic, social, and environmental benefits.

As a monetary authority with a mandate to support inclusive and sustainable economic growth, Bank Indonesia is also focused on strengthening MSMEs through the development of a circular economy ecosystem. This research is expected to formulate a circular economy business model that is applicable and replicable by MSMEs across various regions of Indonesia.

1.2 Research Objectives

This research aims to develop MSME applications based on a circular economy that integrate the processing of organic waste, plastic waste, used cooking oil, and agricultural waste, such as pineapple leaf fiber, into products with economic value. This research also aims to identify the challenges of circular economy implementation across technical, social, economic, and regulatory aspects, and to evaluate its impact on regional economic growth. The main output of this research is a Policy Research Paper (PRP), which will be used comprehensively as input for the formulation of Bank Indonesia's internal policies. Based on the above background, some of the main problems formulated in this study are:
1. What are the challenges and strategies in the implementation of the circular economy in Indonesia, especially at the regional level, seen from technical, economic, regulatory, and social aspects?
2. How can the implementation of a circular economy in Indonesia contribute to increasing labor absorption and economic growth in the regions?

2. Literature Review

2.1. The Concept of Circular Economy

A circular economy is a regenerative economic model that aims to decouple economic growth from the consumption of finite resources by redesigning production and consumption systems. According to the Ellen MacArthur Foundation, the circular economy rests on three main principles: (1) Design out waste and pollution: designing products and systems so that waste and pollution are eliminated from the

start; (2) Keep products and materials in use: maintain the use of products, components, and materials in the use cycle for as long as possible through practices such as reuse, repair, refurbish, and recycling; and (3) Regenerate natural systems: improve and enrich natural systems rather than simply reducing their negative impacts (Ellen MacArthur Foundation, 2013). The concept was developed in response to a linear "take-make-throw" economic model that was considered unsustainable.

Meanwhile, UN Environment emphasized that the circular economy is not only a technical approach to waste, but also part of an inclusive economic strategy that supports the achievement of the Sustainable Development Goals (SDGs), specifically the 12th goal on responsible consumption and production. In developing countries such as Indonesia, the circular economy is also seen as a tool to create green jobs, strengthen local economic resilience, and reduce dependence on increasingly scarce imported resources (Kristianto et al., 2023; Mulyani et al., 2024).

At the theoretical level, the circular economy is also associated with closed-loop systems theory and regenerative economics, which encourage the redesign of production processes so that materials can return to the industrial or natural cycle without producing hazardous waste. This approach is very suitable for the MSME sector, which is highly flexible and can adopt local innovations quickly, thereby becoming an agent of change in Indonesia's transition to a sustainable economy (Nindiya & Kusumastuti, 2025).
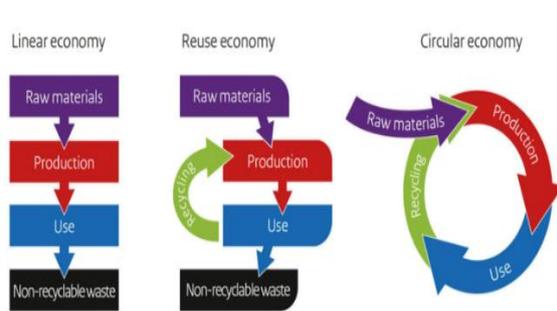

Figure 2. 1 Circular Economy Concept

Source: (Harliyono & Priskilla, 2019)

Figure 2. 2Cradle-to-Cradle Concept

Source: Meyer & Schneider (2019)

Cradle to Cradle (C2C) is a sustainability framework rooted in the principle of regenerative design, first developed by William McDonough and Michael Braungart (2002). In contrast to conventional environmental approaches that focus on reducing negative impacts, C2C offers a new paradigm that aims to generate a net positive impact on the environment and society. C2C "represents innovation, quality, and good design", and encourages the safe and sustainable circulation of materials through two main cycles: the biological cycle and the technical cycle (Meyer & Schneider, 2019). The biological cycle includes consumer products, such as textiles and packaging, that are designed to be biodegradable and to enrich ecosystems. Meanwhile, the technical cycle manages durable industrial materials, such as metals and plastics, for reuse through disassembly, reassembly, and upcycling.

One of the main principles in this theory is the rejection of the idea that waste is an inevitable consequence of production. Instead, C2C emphasizes that "waste is food", hinting that any material, whether natural or synthetic, should have the potential as a nutrient for subsequent processes (Bjørn et al., 2018). This approach is very different from the traditional "reduce, reuse, recycle" concept, which often results in lower-quality materials (downcycling). In the C2C framework, design is directed so that materials can be maintained or even improved in quality through a

cycle known as upcycling. As Kriza (2023) emphasizes, "materials must be designed to be able to be dismantled and reused continuously", indicating that C2C implementation begins from the product design stage.

2.2. Previous Studies

Research conducted by Shobande et al. (2025) examines how the roles of carbon taxes, renewable energy, and circular economy practices affect the effectiveness of government actions and policies in the transition to net-zero emissions. The study used econometric approaches, including time-series analysis, panel regression (POLS, fixed effects, Driscoll-Kraay, etc.), and Generalized Method of Moments (GMM), as well as TL-moment-adapted Quantile via Moment regression models, to capture short- and long-term relationships and data heterogeneity. The results suggest that past policy decisions have a long-term influence on current climate policy direction, with carbon taxes sometimes undermining regulatory efforts, while circular economy practices significantly improve the effectiveness of climate policies.

Research conducted by George et al. (2015) developed a theoretical model of the circular economy to analyze the relationships among economic growth, waste, and pollution by introducing two types of production resources: environmentally polluting inputs and recyclable inputs. Using a closed-economy, no-population-growth framework, this study explores the dynamics of waste and pollution accumulation and the important roles of recycling rates and the environment's natural recovery capabilities in driving sustainability. The analysis shows that environmental quality cannot be maintained or improved solely through economic growth, thereby contradicting the Environmental Kuznets Curve (EKC) hypothesis. In contrast, improvements in environmental quality can only be achieved by increasing the recycling rate or the rate of natural environmental recovery.

Research conducted by Androniceanu et al. (2021) identified and analyzed the contribution of the circular economy to sustainable development, environmental protection, and economic growth across EU member states. The study used 13 key indicators from Eurostat and World Bank databases and applied Principal Component Analysis (PCA) to data from 25 EU member states in 2018 to reduce the data dimension and build a circular economy index. The analysis showed that the three main components explained 70.06% of the data variation, and the developed index provided a performance comparison between countries. The main conclusion of this study is that the circular economy is a strategic option that can be leveraged to create competitive advantage and promote sustainable economic growth.

The research conducted by Fatmawati et al. (2024) is a case study of the Subang Charm Program in Cikadu Village, Indonesia, which examines the transformation of pineapple leaf waste into sustainable eco-fashion products. This study analyzes how the program manages pineapple leaf waste as a raw material for textile fibers, while empowering local communities through training in sustainable practices and job creation in the eco-friendly textile industry. The analysis focuses on aspects of waste recovery, community empowerment, and environmental impacts. The results show that the program effectively reduces carbon emissions, increases waste recycling, and generates economic and environmental benefits, while demonstrating its replicability potential for promoting the sustainability of the textile industry in other regions.

Research by Yuwono et al. (2022) explored the potential of BSF larvae to convert household and industrial organic solid waste into alternative protein sources for animal feed, addressing the challenge of feed security in Indonesia, which remains heavily dependent on imported materials such as fishmeal and soybeans. This study

was conducted in Bogor, using restaurant waste as a larval cultivation medium in a bio-pond for 2 weeks, after which the larvae were dried and ground into protein flour. This product was then tested as a feed mixture for catfish (Pangasius sp.) and one-day-old chickens, with results showing that the BSF-flour-containing feed mixture produced growth comparable to or even better than conventional feed. BSF flour has also been shown to meet most of the parameters of SNI 7548:2009, although there are notes on fat and moisture content in some formulations. From an economic perspective, the use of BSF reduces feed costs, increases waste management efficiency, and opens opportunities for sustainable local protein production at household and industrial levels. Thus, this research not only provides environmental solutions to address the accumulation of organic waste but also strengthens the foundation of a circular economy and an independent local food system in Indonesia.

The research conducted by Nurilma et al. (2020) analyzed the potential for developing creative furniture products from recycled plastics using an eco-design approach in Yogyakarta. This study analyzes six main aspects: the management and processing of recycled plastics; the shape of the furniture produced; the combination of materials; working techniques; dyeing; and the type of plastic used. Using a qualitative descriptive analysis method, the study found that plastic waste collection in Yogyakarta remains slow, but Eco bricks can serve as a basis for making furniture covered with vinyl fabric or textiles, such as batik, to increase aesthetic value. Recycled plastic can also be combined with other materials and processed using a variety of working techniques, resulting in attractive, colored products. Plastic types that could be used include PET, PP, and other plastic blends.

Research conducted by the National Team for the Acceleration of Poverty Alleviation (TNP2K) (2023) analyzed the potential use of used cooking oil as a raw material for biodiesel and its impact on poverty alleviation in Indonesia. The study evaluated national cooking oil consumption, the volume of used cooking oil generated, and the extent of its utilization for biodiesel production, recycling, and export. The analysis shows that in 2019, out of about 16.2 million kiloliters of cooking oil consumption, only about 3 million kiloliters of used cooking oil were produced, and less than 570 thousand kiloliters were used to produce biodiesel. Most of the used cooking oil is recycled and exported. This research also shows that using used cooking oil for biodiesel can reduce greenhouse gas emissions, create jobs, and provide an additional source of income for the community, especially in the informal sector. However, challenges such as the low collection rate of used cooking oil and the lack of processing infrastructure remain major obstacles to optimizing its utilization.

3. Methodology

This study uses primary and secondary data. Primary data is qualitative data obtained from Focus Group Discussions (FGD) and interviews. Meanwhile, secondary data were obtained from national data sources, including the BPS and other sources supporting this research. Secondary data includes: SUSENAS, SAKERNAS, and the 2016 Provincial Input-Output Table for 52 Industries for West Java, East Java, West Sumatra, and South Sumatra Provinces. The methodology is mixed-methods, combining quantitative and qualitative research methods. The quantitative method will be Cost-Benefit Analysis. Meanwhile, the qualitative research method will optimize FGD and interview activities to dig deeper into information related to the research topic.

3.1. Cost Benefits Analysis

The Cost-Benefit Analysis approach evaluates the economic feasibility of implementing the circular economy approach for Micro, Small, and Medium Enterprises (MSMEs). The analysis was carried out by comparing the total costs incurred with the benefits obtained from circular-based business activities. This evaluation aims to provide a comprehensive overview of potential economic benefits, business efficiency, and contribution to environmental and social sustainability. Thus, the results of this analysis can serve as a basis for consideration in developing circular businesses in the MSME sector.

Net Present Value (NPV) is a financial analysis method used to calculate the difference between the present value of total benefits (revenue) and total costs incurred during the project period, taking into account the time value of money through the discount rate. Benefit-Cost Ratio (BCR) is an analysis method used to compare the present value of all benefits with the present value of all costs over the project period. The calculation formula is:

$$NPV = \sum_t^T \frac{Bt-Ct}{(1+r)t} \quad BCR = \frac{\sum_t^T \frac{Bt}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}}$$

where T is the project period, Bt is the revenue in the t-th year, Ct is the cost in the t-year, and r is the discount rate. If the NPV calculation is greater than zero (NPV > 0), then the project or venture is considered economically viable because it provides a net profit after considering the time value of the money. On the other hand, if the NPV is negative, then the project is considered unprofitable and should not be carried out. For BCR, If the BCR value is greater than 1 (BCR > 1), then the project or venture is considered feasible because the benefits obtained are greater than the costs incurred. Conversely, if the BCR is less than or equal to 1, the project is considered economically inefficient.

The Payback Period (PP) is used to measure how long it takes for the initial investment of a project to return through the benefits or annual income earned. The calculation formula is:

$$PP = \frac{I}{Ab}$$

where I is the total cost of investment required (in Rupiah), and Ab is the net benefit or income earned each year. If the Payback Period is shorter than the business's economic life, the project or business is considered feasible because the investment can be recovered before the business stops operating. On the other hand, if the PP exceeds the business life, the project is considered inefficient in terms of return on capital.

In addition, a Social Benefit Cost Ratio (SBCR) analysis was conducted to assess the extent to which a business activity not only provides financial benefits but also produces social and environmental value that can be quantified financially. SBCR provides an overview of the number of social benefits generated per rupiah invested in a project or business. The calculation formula is:

$$SBCR = \frac{\sum_t^T \frac{Private\ Benefits}{(1+r)^t} + \sum_t^T \frac{Social\ Benefits}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}}$$

Where the present value of social benefits is the present value of all social benefits obtained, such as waste reduction and job creation, while the present value of

investment is the total present value of the investment costs incurred to run the project.

If the value of SBCR is greater than 1 (SBCR > 1), the project or business is considered to provide greater social benefits than the investment costs, so it is socially feasible. Conversely, if the value of SBCR is less than or equal to 1, the project is considered less efficient at creating social value from the investment.

3.2. Input-Output Table

The input-output model is a quantitative framework that maps the flow of goods and services between sectors in an economy. The table shows how much of a sector's output is used as input by other sectors and how much is used for final demand, such as household consumption, investment, exports, and government spending. With this structure, policymakers can trace how changes in demand in one sector ripple through the supply chain and affect output, income, and employment opportunities.

The input–output model provides a tool to analyze sectoral linkages. Backward linkage shows how strongly a sector attracts upstream activity because of its need for raw materials and intermediate services. The future linkage shows the role of a sector as an input supplier to downstream sectors. The findings of linkages help policymakers identify priority sectors, design interventions to strengthen supply chains, and identify potential import leakages that could weaken domestic impacts.

In this study, we use the regional Input-Output Table because the MSMEs studied are still very localized, limiting the impact at the national level. The regional approach is more appropriate for capturing upstream and downstream linkages in MSMEs' operational areas. We also note an important limitation: the availability of the latest BPS regional I-O Table, which is still from 2015 and may not fully reflect the current economic structure.

The I-O model was then compiled for each region based on the locations of pilot MSMEs representing four types of circular economy businesses: BSF-based organic waste management in Banten, recycling-based eco-furniture in West Java, pineapple leaf-based eco-fashion in South Sumatra, and used cooking oil processing in East Java. This region-based approach allows for more contextually relevant multiplier estimation.

4. Results / Analysis

4.1. Black Soldier Fly (BSF)

Indonesia faces structural challenges in the waste management system, especially in the organic waste sector (Hendra, 2016). Based on data from the National Waste Management Information System (SIPSN, 2025), the volume of national waste exceeds 34.9 million tons per year, with the largest portion coming from organic waste. Based on the projection of Indonesia's Business as Usual (BAU) Food Loss and Waste (FLW) for 2020–2045, conducted by Bappenas, FLW generation is projected to reach 45–112 million tons per year, or 165–344 kilograms per capita per year (Bappenas, 2021). The increase occurred throughout the food production supply chain, especially in the production (4.36%), distribution and marketing (5.10%), and consumption (17%) stages. This increase is triggered by three main factors: (i) population growth, economic growth that increases GDP and GDP per capita, and an increase in food demand per capita per day (Bappenas, 2021). Organic waste disposed of in landfills (landfills) contributes significantly to methane

emissions, a greenhouse gas with 28 times greater global warming potential than carbon dioxide (Globe, 2021).
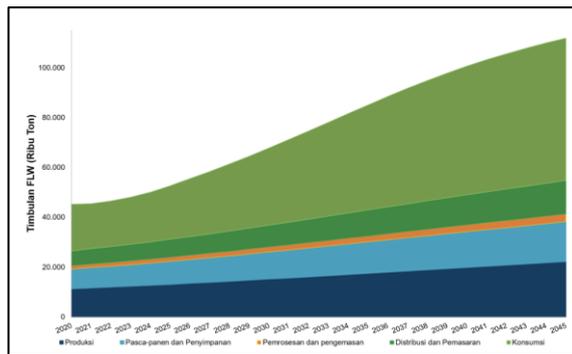
Graph 4. 1 FLW Generation Projections 2020 – 2045
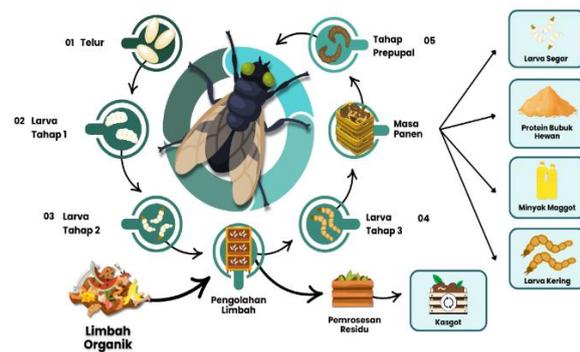
Source: BAPPENAS (2021)

Figure 4. 1 BSF Circular Process

Source: Authors

BSF cultivation is a business that implements a circular process by producing maggots that eat organic waste from black flies (Hermetia Illucens), a type of sustainable waste management technology. This cultivation is done through bioconversion, in which BSF converts various types of organic waste into high-value biomass (Fitriana et al., 2021; Ichwan et al., 2021; Indri et al., 2021; Sanjaya et al., 2019; Widyastuti et al., 2021). Through bioconversion, BSF can reduce waste, recover resources (proteins and oils), and recycle nutrients through frass (organic fertilizer), with relatively low land and water requirements compared to conventional systems. The results showed that BSF reduced organic waste volume by 40–85% within 1–3 weeks. Research by Ibadurrohman et al. (2020) reported a recycling efficiency of 75% with larval biomass production reaching 800 grams from 4 kilograms of waste. BSF is a species that naturally adapts to tropical and subtropical climates and has a high ability to decompose organic matter, both plant and animal (Hopkins et al., 2021; Singh & Kumari, 2019). Indonesia's hot, humid climate makes it an ideal environment for BSF cultivation as an organic waste management technology, which is the main waste problem in Indonesia (Ojha et al., 2020).

BSF larvae contain high levels of protein (40–54%) and fat (15–49%), making them of high economic value both as feed raw materials and for various industrial applications (Kim et al., 2019; Spranghers et al., 2017; Kinasih et al., 2020; Nyakeri et al., 2017). BSF larvae can be processed into products such as dried larvae, protein flour, or extracted oil, with protein quality comparable to that of soybean flour (Čičková et al., 2015). Its protein content includes ten essential amino acids that are essential for animal growth, namely arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine (Halver et al., 1957; Halver & Shanks, 1960; Shumo et al., 2019b). This amino acid profile depends on the type of organic waste substrate used during rearing; larvae fed kitchen waste show the highest total amino acid content (Shumo et al., 2019b). Sustainable alternatives that can replace soybean and fishmeal, while reducing dependence on conventional feed sources and contributing to food security through diversification of protein sources (Surendra et al., 2020). In addition, BSFL contains bioactive compounds, such as antimicrobial peptides, that have the potential to improve immune function and feed efficiency in farm animals (Surendra et al., 2020). In addition to feed, bioconverted proteins and fats, BSF also has wide applications in various industrial sectors, including biodiesel production, biopolymer (chitin) manufacturing, and soil composting (Leong et al., 2015; Lu et al., 2021; Tanga et al., 2021; Purkayastha & Sarkar, 2022). From an environmental perspective, BSF

products are proven to be 2–5 times more environmentally friendly than conventional feed sources (Smetana et al., 2016). Research by Ermolaev et al. (2019) reported that the organic waste treatment process using BSF produces very low greenhouse gas emissions (CH_4 and N_2O) and does not cause ammonia (NH_3) emissions.

The BSF MSMEs business model starts with collecting organic waste from various sources, including households, traditional and modern markets, restaurants, and grocery stores. Organic materials, such as leftover vegetables, fruits, and food waste, are collected by waste management services, sorted, and processed before being distributed to BSF MSMEs as the main raw materials. The bioconversion process is carried out by cultivating BSF larvae, which efficiently decompose organic matter. The harvested larvae are then processed into various products, including high-protein animal feed for poultry and fish, maggot oil, and liquid and solid organic fertilizers derived from the cultivation medium residue. This production process can be supported with equipment such as dehydrators, grinders, mixers, and fertilizer sieving machines to ensure efficiency and maintain the quality of the final product.

In its operational process, BSF MSMEs can be supported by financing institutions and the government, for example, through Bank Indonesia's strategic role in strengthening the value chain and green financing capacity. Through financing business-matching facilitation, Bank Indonesia can bring together MSME actors with green financial institutions to access environmentally friendly credit schemes tailored to the characteristics of micro businesses. This support allows MSMEs to invest in efficient production technology and environmentally standard cultivation facilities. In addition, the adoption of digitalization through applications such as SiApik for financial record-keeping, BISAID for access to financing and mentoring, and the Green Calculator for energy efficiency and emission measurement can help increase the transparency of the performance and feasibility of financing green MSMEs.

Bank Indonesia plays an important role in strengthening the competitiveness of BSF MSME products by facilitating certification and standardization. The certification process is carried out by a certification body that ensures the product meets quality, safety, and sustainability criteria. Certifications such as the Indonesian National Standard (SNI) for fertilizers and feed, ecolabels, ISO 14001, and the Global Feed Standard are important instruments for BSF products to be recognized in the domestic and global markets. This certification can increase the credibility of BSF products, open export opportunities, and expand the marketing network.

BSF's business model creates a closed, integrated circular economy cycle across sectors. BSF MSME processed products, such as organic feed and fertilizers, are used in the agriculture and livestock sectors to support sustainable production. Furthermore, these agricultural and livestock products are marketed to both traditional and modern markets, which then distribute them to various outlets such as households, restaurants, catering, and the food industry. From the entire chain, the remaining organic waste will be collected by the waste management service and processed into new raw materials for BSF MSMEs. This cycle creates an efficient, sustainable zero-waste system and strengthens connectivity among the agriculture, livestock, and waste management sectors. With government policy support, green financing, and the application of circular economy principles, BSF MSMEs have the potential to be pioneers in developing the bioconversion industry at the local level and to have a positive impact on the environment, the economy, and the social community.
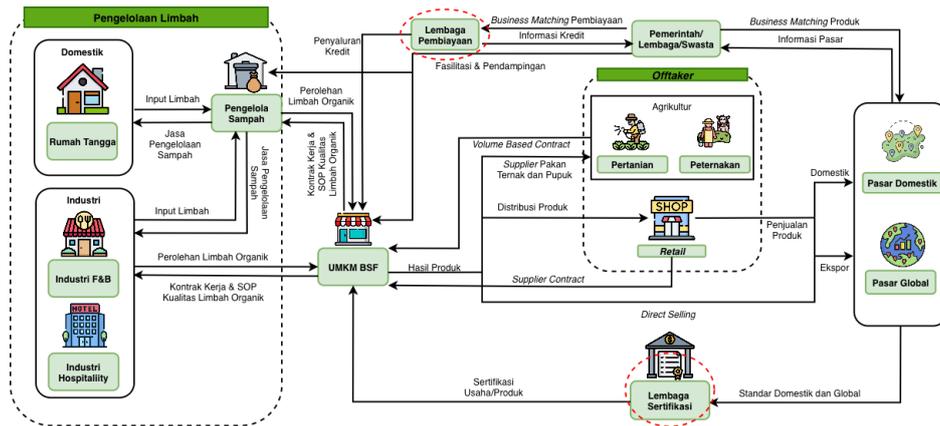
Figure 4. 2 BSF MSME Business Model

Source: Authors

The financial feasibility analysis was conducted to assess the prospects of the BSF cultivation business using the Cost-Benefit Analysis (CBA) approach. The calculation includes the payback period (PP), net present value (NPV), and benefit-cost ratio (BCR) to provide a comprehensive picture of potential profits and business efficiency in the medium term.

Table 4. 1 Cost Benefit Analysis MSME BSF

Component	Estimated Cost
Initial Investment	Rp315.400.000
Operating Costs and Raw Materials	Rp348.826.000
Income	Rp433.566.000
Profit	Rp84.740.000
Payback Period	3 years 7 months

The initial investment of IDR 315,400,000 in the BSF cultivation business can be recovered in about 3 years and 7 months, with an annual net profit of IDR 84,740,000. This return period is relatively short for the MSME scale, so that the BSF cultivation business can immediately generate a surplus after passing the third year.

$$NPV = \left(\frac{Rp84.740.000}{(1+5\%)} + \frac{Rp84.740.000}{(1+5\%)^2} + \frac{Rp84.740.000}{(1+5\%)^3} + \frac{Rp84.740.000}{(1+5\%)^4} + \frac{Rp84.740.000}{(1+5\%)^5}\right)$$
$$- Rp315.400.000 = Rp51.479.853$$

The NPV calculation with a 5% discount rate over 5 years yields a value of IDR 51,479,853. This figure is much higher than the initial investment cost, thus confirming that the operating cash flow can provide a significant excess value. The large NPV also shows that the BSF cultivation business is not only feasible in the short term but also promises sustainable financial gains within the five-year analysis horizon.

$$BCR = \frac{\sum_t^T \frac{Bt}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}} = \frac{Rp1.877.113.000}{Rp1.510.234.000} = 1{,}24$$

The results of the BCR analysis showed a ratio of 1.24, indicating that every Rp1 in costs incurred yielded Rp1.24 in economic benefits. This value indicates consistent cost efficiency and profitability throughout the business period. With a

BCR greater than 1, the BSF cultivation business can be considered financially feasible while supporting business sustainability by converting organic waste into value-added products.

Most of the food waste in Indonesia has not undergone composting and still enters the Final Processing Site (TPA) or landfill. Food waste that enters the landfill will emit methane gas. Every 1 kilogram of food waste can produce 0.25 to 0.5 cubic meters of methane gas (CH_4) during anaerobic decomposition. Methane gas has 28 times more potent global warming potential than carbon dioxide (CO_2). This calculation indicates that 1 kg of food waste can produce 0.1–0.2 kg of CH_4, equivalent to 2.8–5.6 kg of CO_2e (carbon dioxide equivalent). Based on the calculation of GHGs that refer to the Environmental Protection Agency (EPA) emission factors (2025), amounting to 0.68 tons of CO_2e per ton of food waste, BSF MSMEs with a capacity of 84 tons per year have the potential to reduce emissions of around 57.12 tons of CO_2e that occur if food waste is disposed of in landfills. Not only carbon emissions, but organic waste is also a source of food for pests such as flies, rats, and cockroaches, which act as vectors for diseases such as diarrhea, leptospirosis, and dengue fever. In addition, the accumulation of organic waste in landfills can degrade soil and water quality due to the decomposition process, which releases bacteria and toxic substances.

From the processing of 84 tons every year, the social impact produced is as much as:

$$Social\ Benefits$$
$$= Amount\ of\ organic\ waste\ processed\ (kg)$$
$$\times Social\ impact\ of\ organic\ waste\ per\ kg = 84.000\ kg\ \times Rp1.500/kg$$
$$= Rp126.000.000$$

Every year, the social impact provided by BSF MSMEs is 126 million rupiah. If we incorporate it into the SBCR calculation:

$$SBCR = \frac{\sum_t^T \frac{Private\ Benefits}{(1+r)^t} + \sum_t^T \frac{Social\ Benefits}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}} = \frac{Rp2.422.627.060}{Rp1.510.234.000} = 1,60$$

The results of the SBCR analysis show a ratio of 1.60, indicating that every Rp1 in costs can generate Rp1.60 in economic benefits, including both private and social benefits. This value is higher than the private BCR, which reaches only 1.24, indicating that BSF MSMEs provide significant social benefits, especially by reducing food waste and its associated environmental impact.

BSF business actors generally still operate facilities with limited capacity, so scaling up to meet market demand requires substantial investments, especially in maggot-drying equipment, maggot-oil extraction, packaging, raw-material storage, and breeding rooms. This limited infrastructure leads to limited production and hinders achieving economies of scale. In addition, the relatively high initial operational costs and waste treatment also create cost pressures, especially for MSME actors who generally do not have structured financial statements. This condition makes financial institutions hesitant to distribute financing. For this reason, more transparent, structured financial reporting is needed to meet the requirements for obtaining green banking credit. Beyond the financing methods mentioned earlier, investment partnership models, such as public-private partnerships, can be used to finance the procurement of productivity support machines during the scaling-up process.

The lack of digital marketing results in a lack of modern distribution networks, hindering new market penetration, especially in local premium segments (organic poultry feed, aquaculture). It is possible to prepare a digital marketing and e-commerce training program designed with practical modules and field mentoring. The establishment of the regional BSF cluster will encourage collaboration among business actors, support university applied research and facilitate corporate buyers. Thus, the BSF ecosystem can grow synergistically, strengthening bargaining power and business sustainability.

The integration of the three strategies above, the management of raw material supply, structured financing, and the improvement of human resource capabilities, must be carried out on an ongoing basis through monitoring and evaluation mechanisms. Follow-up recommendations include establishing regular forums among industry players, academics, and regulators to facilitate technological innovation and support policies (see appendix).

In analyzing the potential economic impact of investment in the plastic waste processing sector, the Input-Output Model is used. By disaggregating the water procurement, waste, and recycling management sectors, as well as MSME market share, the contribution of BSF MSMEs to the regional economy in West Sumatra Province can be calculated.

Table 4. 2 Coefficients Table I-O West Sumatra

West Sumatra I-O Table Coefficients for BSF MSMEs	
Output Multiplier	1,23
Regional GDP Multiplier	0,50

The estimated results show that the output multiplier for BSF MSMEs is 1.23, meaning that every additional final demand of Rp1 in the BSF sector can increase total economic output by Rp1.23. Meanwhile, the regional GDP multiplier (GDP multiplier) was recorded at 0.50, which shows that every additional Rp1 final demand from the BSF will increase the Gross Regional Domestic Product (GDP) of West Sumatra by Rp0.50.

Based on an investment simulation of IDR 1 billion, a projected increase in output of IDR 1.23 billion and an additional contribution to GDP of IDR 500 million were obtained. In addition to contributing to regional economic growth, this activity also increases labor absorption by creating around 148 new jobs, including 30 formal and 118 informal workers. This impact means that investment in the BSF MSME sector can provide economic added value while creating wide job opportunities for local communities, especially in the lower middle class.
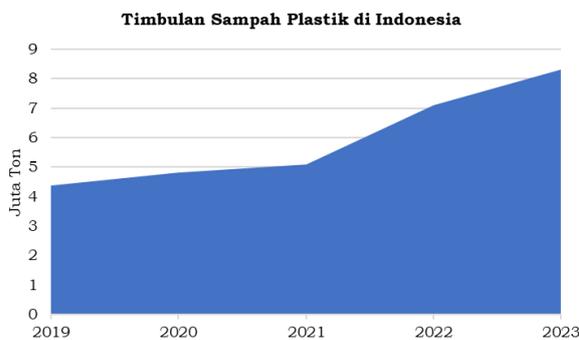
4.2. Eco Furniture Design

Plastic Waste Processing MSMEs or Eco Furniture Design is a business actor that focuses on optimizing plastic waste, one of the biggest environmental problems, into value-added products that are functional and aesthetically appealing. These MSMEs prioritize the principles of sustainable development by integrating economic, social, and environmental aspects in their business activities. This approach supports the circular economy by recycling plastics into furniture, accessories, and other eco-friendly products.

The urgency of this business is increasing alongside the high production of plastic waste in Indonesia, which reached more than 8 million tons in 2023, making it the second-largest contributor to waste (19.6%), after food waste (37.8%) (SIPSN, 2025). This great potential shows the green economy opportunities that can involve

people from the household level to the creative industry in turning waste into a commodity of economic value.

MSMEs Eco Furniture Design is a business motivated by the problem of the large generation of plastic waste that has not been optimally managed in Indonesia. By adopting a circular-economy-based business model, these MSMEs are not only profit-oriented but also carry a social and environmental mission to reduce plastic waste and create environmentally friendly products of high economic value. This circular approach makes MSMEs an important part of the national waste management ecosystem, where plastic waste is reused as the primary raw material for furniture products and accessories with aesthetic designs.

The business chain starts with the collection of plastic waste sourced from households, waste banks, and TPS3R, and delivers it to collectors. The raw materials collected are then managed by waste managers, who act as suppliers to waste management start-ups. The start-up carries out sorting, cleaning, and quality checks of materials before distributing them to Eco Furniture Design MSMEs. This partnership brings together the waste management sector and the creative industry based on recycling, while strengthening the circular economy value chain at the local level.

Graph 4. 2 Generation of Plastic Waste in Indonesia
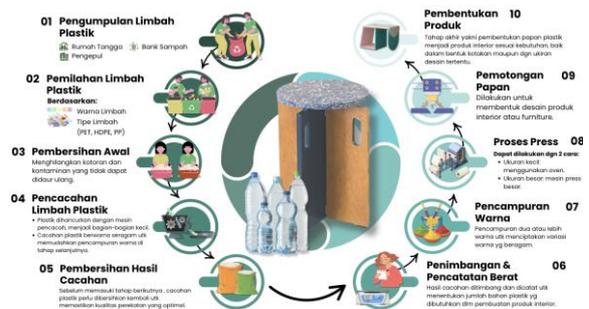
Source: SIPSN (2025)

Figure 4. 3 Business Process of MSMEs Eco Furniture Design

Source: Authors

In the production process, MSME Eco Furniture Design utilizes various supporting machines, such as shredders, injection machines, presses, and extruders, depending on the type of product being produced. The use of these machines increases the efficiency of the material-forming process while enabling the diversification of products in various shapes and sizes. The production stage also involves elements of creative design and finishing, ensuring the final product has both practical function and aesthetic value. The products are very diverse, ranging from accessories like coasters, tumblers, and table clocks to interior furniture such as tables and chairs made from recycled plastic.

In marketing, MSME Eco Furniture Design implements a hybrid strategy that combines offline and online approaches. Offline sales are conducted through participation in exhibitions, bazaars, and physical stores, which allow consumers to see products firsthand. Meanwhile, online marketing is carried out through social media, which serves as a promotional channel and a direct means of communication with consumers. Although e-commerce use is still limited, its development potential is huge for expanding market reach, both domestically and globally. In addition, public education activities and workshops are part of a marketing strategy aimed at increasing public awareness of the importance of recycling and sustainable lifestyles.

The government, in this case Bank Indonesia, has a strategic role in strengthening the value chain and the competitiveness of MSMEs through business-matching facilitation across marketing and financing. Through marketing business matching, Bank Indonesia can bring together MSME players with potential buyers, distributors, and industry partners committed to Environmental, Social, and Governance (ESG) principles, both in domestic and global markets. On the other hand, financing business matching can encourage the availability of credit schemes or green financing with requirements that are adaptive to the characteristics of small businesses. This approach is important for helping MSMEs invest in environmentally friendly production equipment, such as shredder machines, pressing machines, and other production support machinery.

In addition, the government can also facilitate product certification and business standards, both at the domestic and global levels, so that MSME products meet quality, safety, and sustainability criteria recognized by the international market. Certifications such as SNI for recycled products, ecolabel certifications, and global sustainability certifications such as ISO 14001 or the Global Recycled Standard (GRS) can strengthen product credibility in consumers' eyes and open up export opportunities. This facilitation support can increase product value, expand market reach, and accelerate MSMEs' transformation into competitive green enterprises.
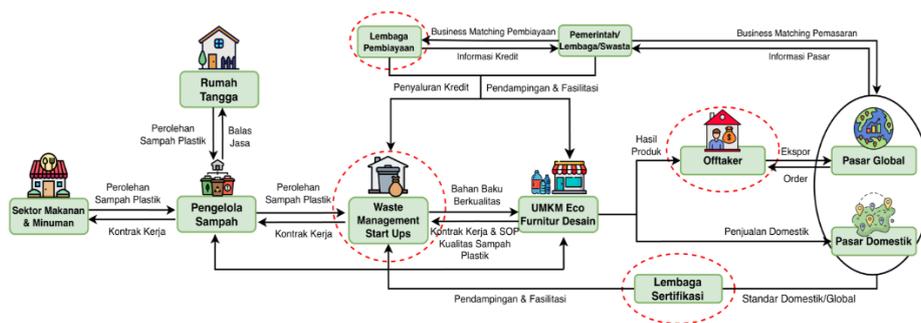

Figure 4. 4 Business Model of MSMEs Eco Furniture Design

Source: Authors

In analyzing the feasibility of the Eco Furniture Design MSME business, the CBA method is used as one of the financial evaluation instruments. This analysis aims to assess the extent to which the investment and operational costs incurred can provide benefits in the form of income and net profit. Through this approach, it can be determined the business's ability to generate profits, the payback period, and the potential for future business sustainability. The results of the CBA calculation for MSME Eco Furniture Design are shown in the following table.

Table 4. 3 Cost Benefit Analysis of MSMEs Eco Furniture Design

Component	Estimated Cost
Initial Investment	Rp220.000.000
Operating Costs and Raw Materials	Rp147.000.000
Income	Rp200.000.000
Profit	Rp53.000.000
Payback Period	4 Years 2 Months

Based on the table, the total initial investment cost for MSME Eco Furniture Design is IDR 220,000,000. This investment expenditure includes land rent, the

construction of workshops, the purchase of shredders and injection machines, and other supporting equipment.

In the production process, Eco Furniture Design MSMEs incur operational costs and raw materials totaling IDR 147,000,000. The costs incurred include raw materials, labor, electricity, packaging, maintenance, and other operational costs.

In its business, MSMEs Eco Furniture Design obtained a nominal amount of IDR 200,000,000 in one year. The nominal is obtained through the sale of interior design products, accessories, and furniture. Based on this income, these MSMEs earn a profit of IDR 53,000,000 over 1 year, or around IDR 4,416,000 per month, with a payback period of about 4 years and 2 months. This finding aligns with research on the business of producing Eco blocks from plastic waste, which indicates a payback period of around 4 years and 2 months (Karunianto, 2024).

$$NPV = \left(\frac{Rp53.000.000}{(1+5\%)} + \frac{Rp53.000.000}{(1+5\%)^2} + \frac{Rp53.000.000}{(1+5\%)^3} + \frac{Rp53.000.000}{(1+5\%)^4} + \frac{Rp53.000.000}{(1+5\%)^5} + \frac{Rp53.000.000}{(1+5\%)^6}\right) - Rp220.000.000 = Rp49.050.000$$

Based on the analysis results, the NPV at the six-year horizon wasis IDR 49,050,000. The six-year horizon was chosen conservatively based on the estimated initial investment life. If the asset can operate for more than seven years, the NPV is expected to increase.

$$BCR = \frac{\sum_t^T \frac{Bt}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}} = \frac{Rp1.768.740.000}{Rp986.126.000} = 1,03$$

The Benefit-Cost Ratio (BCR) for Eco Furniture Design MSMEs is 1.03. Because BCR is greater than 1, investments are considered efficient and have the potential to generate economic profits.

According to EPA (2025) estimates, solid waste, including plastic, can produce around 2.8 tons of CO_2e per ton. Based on this reference, the processing of plastic waste as much as 18 tons per year, if not processed, and ends up in landfills, can produce around 50.4 tons of CO_2e per year, because the burned plastic undergoes complete oxidation and releases CO_2 into the atmosphere. These emissions contribute significantly to global warming, and the incineration process can also produce additional air pollutants, such as fine particulate matter (PM), NO_x, and other toxic compounds, if not accompanied by adequate emission control systems. From an environmental perspective, large-scale burning of plastic can worsen local air quality while increasing MSMEs' annual carbon footprint, underscoring the need for strategies to reduce waste, substitute materials, or increase recycling capacity as more sustainable mitigation efforts.

To quantify the socio-economic impact of the processing of plastic bottle caps by Eco-furniture MSMEs, this study refers to the research by Tamburini et al. (2025), which estimates that each kilogram of plastic waste can result in a social cost of Rp8,250. This social impact analysis assesses the impact of plastic waste on environmental degradation, human health, and economic activities.

With the existence of Eco-furniture MSMEs that can process 18 tons of plastic waste in a year, the social benefits obtained each year are as great as

$$Social\ Benefits$$
$$= Amount\ of\ Processed\ Plastic\ Waste\ (kg)$$
$$\times Social\ Impact\ of\ Plastic\ per\ kg = 18.000\ kg\ \times Rp8.250/kg$$
$$= Rp148.500.000$$

Every year, the social impact provided by Eco-furniture MSMEs is IDR 148,500,000. If we incorporate it into the SBCR calculation, we get:

$$SBCR = \frac{\sum_t^T \frac{Private\ Benefits}{(1+r)^t} + \sum_t^T \frac{Social\ Benefits}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}} = \frac{Rp1.860.102.000}{Rp966.126.000} = 1,79$$

The results of the SBCR analysis showed a ratio of 1.79, indicating that every Rp1 in costs can generate Rp1.79 in economic benefits, including both private and social benefits. This value is higher than the private BCR, which reaches only 1.03, indicating that Eco-furniture MSMEs provide significant social benefits, especially through their contribution to reducing plastic waste, which has a significant social impact.

The implementation of the circular economy at the regional level faces several interrelated challenges, ranging from productivity and financial challenges to process challenges, institutional support, and digitalization. These challenges need to be addressed through collaborative strategies to strengthen raw material supply chains, improve production efficiency, expand market access, and enhance the competitiveness of circular products.

From a financial perspective, access to financing for MSMEs with a circular business model remains the main obstacle. The green financing scheme has not fully reached small business actors, while the investment needs to upscale production machinery are quite large. In addition, logistics costs tend to increase when the source of raw materials is far from the production site. To overcome this, MSMEs can conduct standardized financial records to facilitate obtaining financing from financial institutions and expand targeted green financing. In addition, sourcing raw materials from waste managers near the production site can help reduce logistics costs and maintain supply chain efficiency.

In the operational aspect, the challenge lies in the stability of raw material supply and the limited types of plastic that MSMEs can process. Not all types of plastic can be recycled economically by MSMEs, and plastic waste collection is still not coordinated effectively. This condition often results in the raw materials supplied to MSMEs being non-uniform in quality and quantity. In addition, the integration of MSMEs with waste managers and waste management start-ups is still minimal, so the supply chain process has not run optimally. The strategy is to establish cooperation contracts with local waste managers to ensure the continuity of raw material supply, as well as to use more advanced production machines so that MSMEs can process various types of plastic waste. In addition, establishing a cooperation agreement with a waste management start-up to provide high-quality waste tailored to the needs of MSMEs.

In terms of support, MSMEs have not optimally utilized the digitization of financial records and emission reporting. The use of e-commerce platforms for marketing is also still low, so the potential of the domestic and global markets has not been fully realized. In addition, the lack of domestic and global standards and certifications for recycled products owned by MSMEs reduces consumer trust in products made from used plastics. For this reason, it is necessary to increase the use of digital applications for financial and emissions recording to enhance

transparency in performance and the measurement of business sustainability. Utilization of E-commerce must be expanded with interactive digital marketing strategies, including collaborations with influencers/campaigns based on environmental narratives to attract public interest. On the regulatory side, the government can facilitate product certification and business standards, such as SNI, Ecolabel, or the Global Recycled Standard (GRS), so that MSME products have domestic and global market recognition and can compete with large industrial products (see appendix).

Based on the analysis, MSMEs in West Java that design furniture from plastic waste have an output multiplier coefficient of 1.95 and a GDP multiplier of 0.67. The value of the output multiplier is relatively high compared to Nurjanah's (2016) results, which found that the processing industry sector, one of the largest contributors to the West Java economy, has an output multiplier of around 1.85. In addition, the sector's GDP multiplier is generally below 0.5 (Widiani & Budhi, 2024). This result shows that Eco Furniture Design MSMEs with a circular business model for plastic waste processing can deliver a competitive economic impact on the regional economy.

Table 4. 4 Coefficients of Table I-O West Java

Coefficients of Table I-O West Java for MSMEs Eco Furniture Design	
Output Multiplier	1,95
GDRP Multiplier	0,67

It is assumed that if 1 billion rupiah is invested in Eco Design Furniture MSMEs based on plastic waste, with an output multiplier coefficient of 1.95, the investment will increase the regional economy's total output by 1.95 billion rupiah. In terms of GDP, with a GDP multiplier of 0.67, the same additional investment will increase the gross regional added value by around 670 million rupiah.

In addition to contributing to GDP, the results of the input-output analysis also allow an assessment of the impact of investment on labor absorption. Each investment of 1 billion rupiah in Eco Furniture Design MSMEs is estimated to create 140 jobs, including 49 formal jobs and 91 informal jobs. The majority of these jobs are in the Plastic Waste Treatment, Water Procurement, Waste Management, and Waste and Recycling sectors.

The increase in GDP and labor absorption can also encourage greater income distribution. This increase is due to most businesses in the plastic waste processing industry being MSMEs, with workers from middle- or lower-middle-class backgrounds. The existence of investment distribution tends to improve people's living standards by offering formal job opportunities with more decent salaries and access to social protection. This impact supports the principle of sustainable development, which prioritizes environmentally friendly and inclusive practices.

4.3. Eco-Fashion

The business models of Eco-Fashion MSMEs based on pineapple leaf fiber are fundamentally different from conventional models. If the conventional model prioritizes financial benefits, Eco-Fashion MSMEs balance profit with social and environmental missions. The principles of sustainability, waste management, and community empowerment, especially for women in rural areas, are the main foundations of her business activities.

The business model of Eco Fashion MSMEs based on pineapple leaf fiber demonstrates the interconnectedness of actors from upstream to downstream in the production of value-added products. In the early stages, farmer groups supply pineapple leaves as the main raw material, while cooperatives handle initial collection and processing to maintain consistent fiber quality. After the fibers are processed into pineapple weaving, Eco Fashion MSMEs can sell them directly to the public, process them into ready-to-wear products, or distribute them to MSMEs Processors who then turn them into clothing, accessories, and various other consumer products. This series of processes illustrates that the success of the ecosystem depends on the collaboration of each actor in accordance with their function in the supply chain.

The part marked with a red circle indicates a point where its capacity is still limited or has not been fully utilized. One of the main challenges is the availability of quality pineapple leaves, which must be sustained to meet production needs. In this context, pineapple leaf collector cooperatives play an important role as liaisons between Eco Fashion MSMEs and farmer groups. Through cooperatives, long-term sales agreements can be established to maintain a stable pineapple leaf supply while providing farmers with certainty about sales and prices. This mechanism helps create a more structured relationship between raw material producers and processing MSMEs.

Figure 4. 5 Business Processes of Eco-Fashion MSMEs Based on Pineapple Leaves
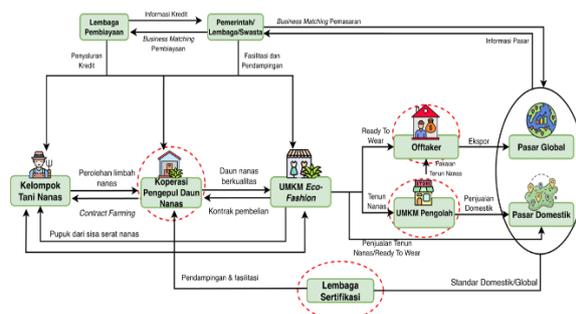
Source: Authors

Figure 4. 6 Eco Fashion MSME Business Model

Source: Authors

On the downstream side, the pineapple leaf fiber market is divided into two main channels: domestic and global. Products can be marketed through MSMEs Processors first or sold directly to domestic consumers. Meanwhile, to penetrate the global market, the presence of off-takers who can distribute products to international distribution networks is needed. Certification bodies also play an important role in increasing the value and credibility of products. Green certifications, such as the Green Industry Certification from the Ministry of Environment and the EU Ecolabel from the European Union, can strengthen product competitiveness and reduce buyers' perception of greenwashing risk. In addition, the government and related institutions serve as facilitators in business-matching marketing and financing, bringing together MSMEs, cooperatives, farmer groups, and financial institutions. This role helps reduce barriers to accessing capital, enabling all parts of the supply chain to increase production scale.

The table below presents an analysis of the cost and performance components of the pineapple leaf-based Eco-Fashion MSME business. The initial investment includes the procurement of pineapple leaf scrapping machines, fine non-machine looms (ATBMs), sewing looms, and production sewing machines.

Annual operating costs include employee salaries, the purchase of pineapple leaves and natural dyes, and electricity and water costs. In one year, MSMEs processed 1.2 tons of pineapple leaves purchased for Rp50,000 per kilogram. Each kilogram of pineapple leaves is processed into five meters of mat sheets with a processing cost of IDR 150,000 per meter.

The total annual operating cost is around IDR 90,000,000 to produce 5,000 mats. Each mat costs IDR 300,000, so the annual income is IDR 150,000,000. Thus, the annual profit is around IDR 54,000,000. To return the initial investment of IDR 200,000,000, it takes 3 years and 5 months. This calculation aligns with previous research, which found that the payback period for circular-economy-based MSMEs is longer than that of MSMEs in general (Nugraheni et al., 2019).

Table 4. 5 Cost Benefit Analysis of Eco-Fashion MSMEs

Component	Estimated Cost
Initial Investment	Rp200.000.000
Operating Costs and Raw Materials	Rp90.000.000
Income	Rp150.000.000
Profit	Rp60.000.000
Payback Period	3 Years 5 Months

The NPV calculation shows that over five years, the NPV reached IDR 59,770,000. The five-year term is chosen conservatively based on the estimated life of the initial investment. If the asset can operate for more than five years, the NPV will also increase.

$$NPV = \left(\frac{Rp60.000.000}{(1+5\%)} + \frac{Rp60.000.000}{(1+5\%)^2} + \frac{Rp60.000.000}{(1+5\%)^3} + \frac{Rp60.000.000}{(1+5\%)^4} + \frac{Rp60.000.000}{(1+5\%)^5} \right) - Rp200.000.000 = Rp59.770.000$$

The Benefit-Cost Ratio (BCR) of Eco-Fashion MSMEs is 1.11. Because BCR is greater than 1, investments are considered efficient and have the potential to generate economic profits. Overall, all cost-benefit analysis indicators show that pineapple leaf-based Eco-Fashion MSMEs are financially viable and have strong prospects. This finding is proof that the circular economy-oriented MSME model does not have to be economically detrimental and instead holds significant profit potential.

$$BCR = \frac{\sum_t^T \frac{Bt}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}} = \frac{Rp649.420.000}{Rp589.652.900} = 1,11$$

All indicators from the Cost-Benefit Analysis indicate that pineapple leaf-based Eco-Fashion MSMEs are a viable, economically profitable business. These results confirm that the MSME model with a circular-economy orientation is not synonymous with losses but can generate significant profits while supporting sustainability principles.

The rest of the pineapple leaves that are not used in MSME processing will mostly be burned or sent to the landfill. Similar to food waste, pineapple leaf waste that enters the landfill will emit methane gas. Every 1 kilogram of food waste can produce 0.25 to 0.5 cubic meters of methane gas (CH_4) during anaerobic decomposition. This calculation means that 1 kg of pineapple leaf waste can produce about 0.1–0.2 kg CH_4, which is equivalent to 2.8–5.6 kg of CO_2e (carbon dioxide equivalent) (Chaves et al., 2024).

To calculate the emissions emitted from the decaying pile of pineapple waste, a standard from the EPA (2015) is used. Every ton of decaying pineapple leaf waste will produce emissions of 0.12 kg of CO2e. If MSMEs can process 12,000 kg of pineapple leaf waste every year, then MSMEs have reduced the potential for GHG emissions by 1,440 kg of CO2e per year. In addition, the natural decomposition of pineapple leaves without management produces various volatile compounds, including ammonia, hydrogen sulfide, and organic acids, which cause pungent odors and local air pollution (Puspitasari et al., 2014). If burned openly, which is still a common practice on small-scale farmland, this waste releases carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (N_2O), and ammonia (NH_3) that contribute to climate change and air pollution, while also causing respiratory irritation for residents (Jalil et al., 2024).

According to EPA (2015), processing 12,000 kg of pineapple leaves per year that end up in landfills could generate about 3,360 tons of CO_2e per year, mainly from methane (CH_4) produced under anaerobic conditions during decay. These emissions arise from calculations of IPCC-standard parameters, such as DOC, DOCf, MCF, and methane gas fractions, thereby reflecting the true potential of organic waste when not handled aerobically. From an environmental perspective, methane releases contribute significantly to global warming, while the accumulation of organic biomass in landfills can worsen soil quality and increase the risk of leachate pollution.

To quantify the social impact of processing pineapple leaf waste through Eco-Fashion MSMEs, we follow the calculation method from the Asian Development Bank (2021) which estimates the social impact of agricultural waste using the cost of emissions of Rp850,000 per kg PM2.5 from the Copenhagen Consensus Center (2014) combined with the estimated emissions from pineapple leaf waste of 8 grams of PM2.5 per kilogram taken from the research of Shen et al. (2021).

From the processing of 12 tons per year, the social impact produced is as follows:

$$
\begin{aligned}
Social\ Benefits \\
&= Amount\ of\ Waste\ Processed\ (kg) \\
&\times Emission\ Factor\ of\ PM2.5\ per\ waste\ (Kg) \times Emission\ cost \\
&= 12.000\ kg\ \times 0.008 \times Rp850.000/kg\ = Rp81.600.000
\end{aligned}
$$

Every year, the social impact provided by BSF MSMEs is 120 million rupiah. If we incorporate it into the SBCR calculation,

$$
SBCR = \frac{\sum_t^T \frac{Private\ Benefits}{(1+r)^t} + \sum_t^T \frac{Social\ Benefits}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}} = \frac{Rp1.003.549.000}{Rp589.652.000} = 1,69
$$

The results of the SBCR analysis showed a ratio of 1.69, indicating that every Rp1 in costs incurred generated Rp1.69 in economic benefits, including both private and social benefits. This value is higher than the private BCR, which reaches only 1.11, indicating that Eco-Fashion MSMEs provide significant social benefits, especially by reducing pineapple leaf waste, which has many negative environmental impacts.

Pineapple leaf fiber Eco Fashion MSME pain points include four main aspects: productivity, finance, process, and support. Each aspect presents obstacles that affect MSMEs' ability to produce, finance, process, and market products optimally. However, for each pain point, steps MSMEs can take have been identified to reduce these obstacles and strengthen business capacity. By understanding the relationship

between challenges and the actions that can be taken, it becomes clear how MSMEs can strengthen their business foundations while preparing to enter a larger market.

On the financial side, MSMEs face difficulties accessing bank capital, a lack of direct investors, and unstable cash flows due to fluctuating demand. To improve this condition, MSMEs can take advantage of bank access to credit or special financing for the MSME sector. In addition, MSMEs can collaborate with the government, state-owned enterprises, or the private sector through business-matching activities that bring together business actors with prospective funding providers. Securing sales contracts with the textile industry can also help ensure more stable demand, making cash flow more predictable.

To estimate the economic impact of investment in the pineapple leaf processing sector, an input-output model is used. Through the disaggregation of the textile industry and the analysis of MSME market share, the contribution of pineapple leaf-based Eco-Fashion MSMEs to the regional economy in South Sumatra Province can be quantified.

The results of this calculation show that pineapple leaf-based Eco-Fashion MSMEs in South Sumatra have an output multiplier coefficient of 1.69 and a GDP multiplier of 0.58. This value is relatively high when compared to many other sectors in the regional economy. In general, traditional sectors such as primary food agriculture or retail trade only have output multipliers in the range of 1.2 to 1.4 (Widiani & Budhi, 2024).

Similarly, the GDP multipliers of these sectors are often below 0.5 (Widiani & Budhi, 2024). Thus, Eco-Fashion MSMEs are not only able to generate a large chain effect, increasing total output, but are also superior in their contribution to GDP formation compared to several other, more established sectors.

Table 4. 6 Coefficients of Table I-O South Sumatra

Coefficients of Table I-O South Sumatera for MSMEs Eco-Fashion	
Output Multiplier	1,69
GDRP Multiplier	0,58

As an illustration, if there is an investment of 1 billion rupiah in Eco-Fashion MSMEs based on pineapple leaf processing, then based on the output multiplier coefficient of 1.69, the investment will encourage an increase in the total output of the regional economy by 1.69 billion rupiah. In terms of GDP, with a GDP multiplier of 0.58, the same additional investment will increase the gross added value by around 580 million rupiah.

In addition to contributing to GDP, input-output analysis also allows an assessment of the impact of investment on labor absorption. Every investment of 1 billion rupiah in Eco-Fashion MSMEs is estimated to create 116 jobs, comprising 72 informal and 34 formal jobs. The majority of absorption occurred within Eco-Fashion MSMEs and the upstream sector, especially Seasonal Horticultural Crop Agriculture, Annual Horticulture, and Others (as a supplier of pineapple leaves), as well as the Water Procurement, Waste Management, Waste, and Recycling sectors.

This increase in the number of workers affects income distribution. Since most additional job opportunities are in the formal sector, there is potential to improve the living standards of workers who were previously in the informal sector. This impact aligns with the values of Eco-Fashion MSMEs, which emphasize inclusivity and women's empowerment.

4.4. Used Cooking Oil (UCO)

Used Cooking Oil Processing MSMEs are business actors that focus on optimizing used cooking oil, often considered kitchen waste, into high-quality products. These MSMEs have business processes that prioritize aspects of sustainable development, supporting the economy while advancing social and environmental missions. This economic growth involves all economic actors, from households, which produce used cooking oil, to the government and foreign communities, which process it into high-value products. Used cooking oil processing is very important, given the high consumption rate of cooking oil in Indonesia, which reached 12.23 liters per capita per year in 2024 (Ministry of Agriculture, 2024), and which has not been managed optimally. This condition is reflected in the potential for used cooking oil in Indonesia in 2024, estimated at 3.38 million KL from households and corporations (Susenas, 2024).

Used cooking oil, which is often disposed of carelessly by the community, can be used as the main raw material for products with high market value. Used cooking oil is collected from households at a used cooking oil station, which is usually located in residential areas. The collected used cooking oil is then distributed to the local waste bank (usually at the village level) for further storage and filtering. After that, used cooking oil can be processed into two main products: soap and aromatherapy candles.
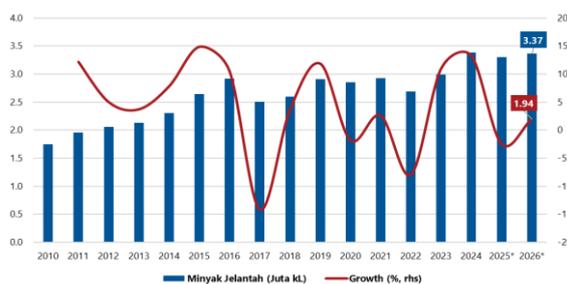
Graph 4. 3 Development of UCO in Indonesia

Source: Susenas (2024); TNP2K (2019)

Figure 4. 7 Business Process of MSMEs in Used Cooking Oil

Source: Author's

Used Cooking Oil MSMEs are businesses motivated by the problem of the large potential of cooking oil waste that is not properly used to improve people's welfare in Indonesia. These MSMEs adopt a circular business model that balances economic benefits with social and environmental considerations. This industry involves various parties at the micro level, namely households, used cooking rice collectors, used cooking banks, waste banks, and traders/factories/hotels in the supply chain that prioritize a sustainable business ecosystem.

In general, Used Cooking Oil MSMEs obtain initial establishment capital from three sources: bank loans, grant funds, and the owner's personal capital. The capital is used to purchase production inputs, such as raw materials like used cooking oil, fire soda, and fragrances. The initial capital is also used to buy capital goods such as machinery, molds, used cooking drums, and warehouse rentals. MSMEs that process used cooking oil also use capital to finance workers' wages. However, Used Cooking Oil MSMEs in general have not received funding from the financial sector, especially from bank loans. In fact, sustainable financing schemes from banks can help MSMEs increase business scale and operations to strengthen liquidity. For example, MSMEs can use sustainable financing to purchase biodiesel processors

that enable biodiesel production as an alternative renewable energy source with a higher selling value.

In relation to the value proposition, Used Cooking Oil MSMEs emphasize transforming used cooking oil waste into aesthetic, environmentally friendly products. Until now, MSMEs have succeeded in producing various products, such as consumer goods (soap and aromatherapy candles), decorations (used cooking flowers), and energy (biodiesel). However, the current regulations in Indonesia related to biodiesel 40 (B40) still do not provide sufficient space for used cooking oil to meet the needs of the national renewable energy mix, as it is still considered dirty. The diversity of products produced is expected to change people's perception of used cooking oil, from what was originally considered waste to a new source of sustainable economic growth.

In terms of marketing, Used Cooking Oil MSMEs employ various strategies to expand their market reach and strengthen their branding. The marketing activities carried out include business collaborations with the industry to market used processed rice products. Other initiatives can be through the program, which aims to increase public awareness about the potential of used cooking oil. In addition, MSMEs participate in exhibitions and workshops to directly demonstrate product quality to consumers while strengthening their interactions with the market.

Used Cooking Oil MSMEs admit that digitalization, especially digital marketing and financial recording, is still not optimal. The use of advertising on social media and campaigns featuring influencer endorsements is also not an option because of the low digital literacy of MSME actors, the majority of whom are elderly and from the region. In the future, this strategy will still have a lot of room to learn, for example, through creative content and the use of more interactive digital marketing features. The digital marketing aspect is very important for strengthening product appeal, especially among young consumers who are active on social media.

The government and Bank Indonesia also play a central role as institutions that have the authority to conduct business matching for both financing and marketing. Through authorities in the financial sector, the government can act as a liaison between used circular MSMEs and financing institutions to support the development of circular MSMEs through financing. In addition, the government supports circular MSMEs that are still constrained by demand by helping conduct marketing business matching, bringing together potential customers for MSMEs. In addition, the government can include UCO products in the product catalog to market them internationally for circular MSMEs that have been export-oriented.

In addition to sales, the Government and Bank Indonesia can also encourage the growth of used cooking oil MSMEs by providing assistance or facilitating access to infrastructure and related infrastructure to support production activities. In this case, the provision of used cooking oil warehouses, production sites, and three-wheeled motorcycles is the most urgent need to increase MSME productivity. In addition, the Government and Bank Indonesia can strengthen MSME human resources' capacity through various training and capacity-building initiatives to ensure that available human resources are qualified and have expertise to support the growth of Used Cooking Oil MSMEs in Indonesia.

Certification bodies are involved in the circular MSME ecosystem by certifying circular MSMEs, waste banks, and other stakeholders to ensure that green or sustainability claims made by used circular cooking oil MSMEs are true and internationally recognized, in line with applicable standards. In addition, soap products used for skin also require BPOM certification to ensure product safety. This

certification is important because, today, global demand for green-labeled products is tightening due to many greenwashing practices that are not in line with the principles of sustainable development.
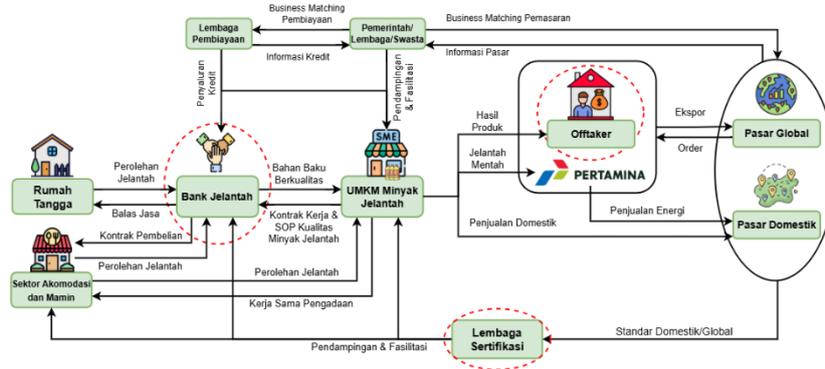

Figure 4. 8 Used Cooking Oil MSME Business Model

Source: Authors

The total annual operating cost is around IDR 127,000,000 to produce 15,000 soaps or candles. Each soap is sold at IDR 5,000 per pack, and aromatherapy candles at IDR 20,000 per pack, so that the annual income reaches IDR 150,000,000. Thus, the annual profit is around IDR 23,000,000. To return the initial investment of IDR 50,000,000, it takes 2 years and 2 months.

Table 4. 7 Cost Benefit Analysis of MSMEs in Used Cooking Oil

Component	Estimated Cost
Initial Investment	Rp50.000.000
Operating Costs and Raw Materials	Rp127.000.000
Income	Rp150.000.000
Profit	Rp23.000.000
Payback Period	2 Years 2 Months

The NPV calculation shows that in a five-year horizon, the NPV reached IDR 49.58 million. The five-year horizon is conservatively chosen based on the initial investment life estimate. If the asset can operate for more than five years, the NPV will also increase.

$$NPV = \left(\frac{Rp23.000.000}{(1+5\%)} + \frac{Rp23.000.000}{(1+5\%)^2} + \frac{Rp23.000.000}{(1+5\%)^3} + \frac{Rp23.000.000}{(1+5\%)^4} + \frac{Rp23000.000}{(1+5\%)^5} \right) - Rp50.000.000 = Rp49.578.000$$

In addition, this study calculates the Benefit-Cost Ratio (BCR) for used cooking oil MSMEs at 1.18. Because the BCR exceeds 1, the investment is considered efficient and has the potential to generate economic profits. Overall, all cost-benefit analysis indicators show that used cooking oil processing MSMEs are relatively financially viable and have strong prospects for further development. This finding is clear evidence that the circular-economy-oriented MSME model can also generate economic profits while retaining significant profit potential for future development.

$$BCR = \frac{\sum_t^T \frac{Bt}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}} = \frac{Rp649.000.000}{Rp549.844.000} = 1,18$$

With this feasibility basis, a broader review of social values through SCBA calculations is needed. The analysis considers the financial benefits received by business actors and estimates the benefits and social costs borne by the community. This approach is important to ensure that the management of used cooking oil is not only economically profitable but also contributes to public health, infrastructure protection, and the strengthening of circular economy systems at the community level.

Using the US Environmental Protection Agency (EPA) approach for greenhouse gas inventories, used cooking oil waste with characteristics similar to vegetable oil has a carbon value of 9.79 Kg CO2e/gallon, or equivalent to 2.84 tons of CO2e/ton. Thus, 2,000 liters of used cooking oil, or 1.82 tons per year, could result in an environmental pollution burden of around 5.17 tons of CO2e per year. If not handled properly, this carelessly discarded used cooking oil can form a film on the water's surface, inhibiting the diffusion of dissolved oxygen and accelerating the decrease in DO. This condition will trigger biological stress on phytoplankton, fish, and decomposing microorganisms. In addition, the anaerobic degradation of used cooking oil can increase methane and volatile fatty acid formation in sediments, worsening eutrophic conditions and accelerating the accumulation of toxic substances such as acrolein and PAHs.

The study also calculated other impacts of used cooking oil, such as the net social value per liter, the value of the per capita loss that has been converted. This step requires a bridge factor, namely, data on per capita UCO production. Based on BPS data on palm oil consumption per capita (11.58 liters per year) and studies on the ratio of used cooking oil generation (an average of 40.02% of consumption), the generation of used cooking oil per capita in Indonesia is estimated at 4.63 liters per year. Thus, the social cost per liter of used cooking oil discarded is obtained by dividing the total economic loss per capita by the generation of used cooking oil per capita. Meanwhile, the calculation of the total social costs that can be used as the basis for the proxy calculation of SCBA is as follows:

$$
\begin{aligned}
Social\ Impact\ &of\ UCO\ (Rp/liter) \\
&= Avoided\ Cost/liter + Economic\ Benefit\ (UCO\ Price/liter) \\
&= \frac{Rp148.000/capita/year}{4.63\ liter/capita/year} + Rp7.000\ /liter = Rp39.000\ /liter
\end{aligned}
$$

With a volume of used cooking oil use of 2,000 liters per year, this UCO produces social benefit as follows:

$$
\begin{aligned}
Social\ Benefits\ &= Amount\ of\ UCO\ (l) \times Social\ Impact\ of\ UCO = 2.000\ l\ \times Rp39.000\ /l \\
&= Rp78.000.000
\end{aligned}
$$

Every year, the social impact provided by used cooking oil MSMEs is IDR 78,000,000. If we incorporate it into the SBCR calculation, the following calculation is obtained:

$$
SBCR = \frac{\sum_t^T \frac{Private\ Benefits}{(1+r)^t} + \sum_t^T \frac{Social\ Benefits}{(1+r)^t}}{\sum_t^T \frac{Ct}{(1+r)^t}} = \frac{Rp987.120.000}{Rp549.844.000} = 1{,}79
$$

This figure implies that every Rp1 invested in the UCO MSME has the potential to generate a socio-economic value of Rp1.79. Based on these results, structured cooking oil management cannot be viewed merely as a waste management activity. This management is a form of strategic public investment that provides high social returns (SBCR > 1). This strategic value arises because used cooking oil management

can function simultaneously as an upstream preventive health intervention, a mechanism for protecting and improving infrastructure, and a driver of an inclusive circular economy.

The community still considers used cooking oil as kitchen waste with no economic value. As a result, people still dispose of used cooking oil waste carelessly, such as dumping it in waterways. This bad habit, if carried out continuously, can lead to the blockage of water channels in residential areas. In addition, used cooking oil is also classified as B3 waste that can contaminate water if not managed properly.

The potential for meeting used cooking oil stocks can be met by non-household producers such as hotels, restaurants, and street vendors. However, these non-household parties are beginning to understand the potential of used cooking oil and tend to manage the waste independently through collaboration with a handful of UCO collectors or environmentally friendly start-ups, which limits the supply of used cooking oil. There are three main reasons for this, including. First, non-household parties want to optimize additional income by distributing used cooking oil only to large players with the highest price/return. The second reason is that some non-household cooking oil producers already have agreements or MoUs with several collectors, so there is no competition for used cooking oil. Third, non-household parties remain skeptical of used cooking oil collectors in general because there is potential for abuse of the distributed used cooking oil.

In terms of production, the main challenge faced is that the production scale is still relatively small. This challenge arises from limited capital, capital goods, raw materials, and labor. The used cooking oil obtained is often of very poor quality due to high sediment. So, MSMEs need time to separate oil and sediment in used cooking tanks. After that, the used cooking oil must still be filtered to ensure its cleanliness and suitability for producing circular products. As a solution, MSMEs can use cooking oil filtering machines that can effectively separate oil from sediment and ensure cleanliness.

In terms of capital goods, used cooking oil MSMEs are still quite limited in the ownership of filtering machines, molds, and used cooking oil warehouses. Printing plays a very important role because the process of forming soap and wax takes a long time to have a hard texture. The limited number of molds severely constrains production capacity, which aligns with MSME productivity levels. In addition, MSMEs are also still having difficulty finding rubber-based molds that can produce attractive product shapes such as flowers and fictional characters.

Used cooking oil processing requires government support, especially for the procurement of filtering machines, freight, and storage. The used cooking oil filter machine effectively separates used cooking oil from its deposits, reducing time and costs. During delivery, used cooking oil entrepreneurs tend to be reluctant to accept small volumes to minimize costs. During storage, used cooking oil remains difficult to handle due to limited storage space and high warehouse rental costs. In fact, the government can contribute by installing used cooking oil collection posts in residential areas and integrating them with local waste banks. This strategy has begun to be implemented, but with relatively limited implementation in some regions. This strategy can simultaneously solve both of the above problems because collectors do not need to spend more money on collecting used cooking oil or on renting a warehouse. In addition, this government contribution can reduce price competition among used cooking oil entrepreneurs, providing input price stability for MSMEs processing used cooking oil.

In addition, accelerating the acquisition of additional certifications is a strategic step that needs to be implemented to strengthen the competitiveness of processed cooking oil products. Green Industry Certification from the Ministry of Industry could be the main selling point, with a focus on sustainability and corporate social responsibility. Meanwhile, to enter the high-value biodiesel export market, obtaining international traceability certifications, such as the International Sustainability and Carbon Certification (ISCC), is a non-negotiable prerequisite. Without compliance with national standards and credible international certifications, used cooking oil products will continue to be trapped in the stigma of waste commodities, making it difficult to accept in market segments with higher levels of profitability (see appendix).

The results of the input-output model estimation show that used cooking oil processing MSMEs in East Java have an output multiplier coefficient of 1.72 and a GDP multiplier of 0.93. Thus, Used Cooking Oil MSMEs are not only able to produce a relatively large chain effect in increasing total output, but are also superior in their contribution to the formation of GDP compared to several other major sectors in the economic structure in East Java

Table 4. 8 Coefficient Table I-O East Java

Coefficients of Table I-O East Java for MSMEs Processing Used Cooking Oil	
Output Multiplier	1,72
GDRP Multiplier	0,68

For example, if there is an investment of 1 billion rupiah in the used cooking oil processing sector in East Java, with an output multiplier coefficient of 1.72, the investment will increase total regional output by 1.72 billion rupiah. In terms of GDP, the same amount of investment with a GDP multiplier of 0.68 will increase gross value added by around 680 million rupiah, indicating an increase in productivity from the distribution of investment in the used cooking oil processing sector.

The input-output model also estimates the impact of a 1 billion rupiah increase in investment on labor absorption. Every additional 1 billion invested in MSMEs processing used cooking oil is expected to create 98 new jobs, comprising 62 formal workers and 36 informal workers. Most of these jobs are in the used cooking oil processing, Water Procurement, Waste Management, and Recycling sectors.

The increase in GDP and labor absorption also contributes to a more equitable distribution of people's income. This condition occurs because, in general, many business actors in the used cooking oil processing sector are MSMEs with workforces from middle- or lower-middle-class backgrounds. The existence of investment distribution tends to improve people's living standards by providing formal job opportunities with a more decent wage level and access to social protection. This impact supports the principle of sustainable development, which prioritizes inclusivity and environmental friendliness.

5. Implication / Policy Recommendation

Based on the results of the research analysis, some of the policy recommendations that can support include:
(1) Encourage the expansion of the number of business actors engaged in the circular economy through the establishment of circular industries at the regional level.
(2) Increasing the role of Local Governments (PEMDA) through the preparation of a green MSME roadmap that is in line with the RPJMN and RPJMD.

(3) Optimizing green financing schemes and green financing business matching, as well as optimizing the digitization of MSME finances by utilizing applications such as SiApik and Green Calculator for transparency of performance and financing feasibility.
(4) Strengthening the technical capacity and infrastructure of MSMEs through the provision of support for production facilities and infrastructure, as well as capacity building to improve the technical skills of workers.
(5) Encourage the acceleration of the expansion of certification and trade promotion to increase credibility, competitiveness, and export opportunities.

6. Conclusion and Further Research

Based on the results of the research analysis, it can be concluded as follows:
(1) The implementation of the circular economy has proven to be financially profitable and has the potential to provide significant social and environmental benefits.
(2) In aggregate, the implementation of the circular economy can contribute to regional economic growth through increased output and labor absorption.
(3) Financing for Circular MSMEs (such as BSF cultivation, Pineapple Leaf Fiber, Plastic Waste Processing, and Used Cooking Oil) from banks is still very limited.
(4) The technical aspect is still the main challenge in the development of Circular MSMEs. Limited production infrastructure, instability in the quality of waste raw materials, and inefficient processing technology make it difficult for productivity and business capacity to develop.
(5) The lack of standardization and certification for Circular MSME businesses or products is an obstacle to credibility, competitiveness, and opportunities for exporting sustainable products.

References

Androniceanu, A., Kinnunen, J., & Georgescu, I. 2021. Circular economy as a strategic option to promote sustainable economic growth and effective human development. *Journal of International Studies (2071-8330), 14*(1).

Apipatpapha, T., Ongkunaruk, P., & Chollakup, R. (2022). Pineapple leaf fiber supply chain analysis for the sustainability of community enterprise: A case study in Thailand. IOP Conference Series: Earth and Environmental Science, 1074(1), 012032.

Asian Development Bank. (2021, October 5). Agricultural and Municipal Waste to Energy Project: Extended Annual Review Report.

Azme, N., Yusoff, S., & Mohd, S. (2023). *Recycling waste cooking oil into soap: Knowledge transfer and community impact in rural Malaysia.*

Barry, T. (2004). *Evaluation of the economic, social, and biological feasibility of bioconverting food wastes with the black soldier fly (Hermetia illucens).*

Bermúdez-Serrano, I. M., & Sánchez-Velázquez, O. (2023). *Comprehensive utilization of the black soldier fly: Bioconversion, sustainability, and emerging challenges. Scientia Agropecuaria.*

Bolong, N., Saad, M., & Yusof, S. (2024). *Feasibility of recycled HDPE planks for sustainable outdoor furnitur: Mechanical properties and user satisfaction.*

Chaves, D. M., Araújo, J. C., Gomes, C. V., Gonçalves, S. P., Fangueiro, R., & Ferreira, D. P. (2024). Extraction, characterization and properties evaluation of pineapple leaf fibers from Azores pineapple. Heliyon, 10(4), e26698. https://doi.org/10.1016/j.heliyon.2024.e26698

Drakulevski, L., & Boshkov, T. (2019). *Circular economy - Creating the future in competitive societies.*

Ebeneezar, S., L. D., Tejpal, C. S., Jeena, N. S., S. R., C. S., S. P., & V. P. (2021). *Nutritional evaluation, bioconversion performance and phylogenetic assessment of black soldier fly (Hermetia illucens, Linn. 1758) larvae valorized from food waste. Environmental Technology & Innovation.*

Ellen MacArthur Foundation. (2013). *Towards the Circular Economy: Economic and business rationale for an accelerated transition.* https://ellenmacarthurfoundation.org

Fasza, N. (2017). *Eksplorasi serat nanas dengan aplikasi sulam sashiko.*

Fatmawati, F., Hidayat, C., Putra, S. A. S., & Kosasih, N. A. 2024. Mengubah Limbah Daun Nanas Menjadi Eco-Fashion Berkelanjutan: Studi Kasus Program PESONA SUBANG di Desa Cikadu, Indonesia. *Dedikasi: Jurnal Pengabdian Masyarakat, 17*(1), 144-174.

Fatmawati, F., Hidayat, C., Sutisna Putra, S. A., & Kosasih, N. A. (2024). *Mengubah limbah daun nanas menjadi eco-fashion berkelanjutan: Studi kasus program PESONA SUBANG di Desa Cikadu, Indonesia. Dedikasi: Jurnal Pengabdian Masyarakat.*

George, D. A., Lin, B. C. A., & Chen, Y. 2015. A circular economy model of economic growth. *Environmental modelling & software, 73*, 60-63.

Harliyono, M., & Priskila. (2019). The Importance of Circular Economy for Indonesia from Business Perspective. *Proceedings of the 2nd International Conference on Inclusive Business in the Changing World.*

Hawanis, H. S. N., Ilyas, R. A., Ahmad, M. H., Xin, C. H., Mahadi, N. K. I., Atiqah, A., Kaur, K., Sapuan, S. M., Muhammad, D., Saharudin, M. S., & Petrů, M. (2025). Recent developments in pineapple (Ananas comosus L.) based biocomposites

and their potential industrial applications: A review. International Journal of Biological Macromolecules, 328, 147531.

Hazwani, M., Abdul Majid, M. S., Azaman, M. D., Ridzuan, M. J. M., & Cheng, E. M. (2024). Mechanical properties and flammability of pineapple leaf fiber (PALF) reinforced polymer composite with hybridized fire retardants. Materials Today: Proceedings, 110, 91–95.

Hidayat, Y. A., Kiranamahsa, S., & Zamal, M. A. (2019). A study of plastic waste management effectiveness in Indonesia industries. *AIMS Energy*.

Irawan, F., Syamsuddin, A., & Kadir, R. (2024). *Utilizing used cooking oil for aromatherapy candle production through community empowerment activities in Lakkang Village, Makassar City.*

Jalil, M. A., Repon, Md. R., Jurkonienė, S., Haji, A., Hussain, S. Z., & Shukhratov, S. (2024). Valorization of pineapple leaves: Effective conversion of agro waste to textile materials. Energy Science & Engineering, 12(6), 2426–2434. https://doi.org/10.1002/ese3.1751

Kementerian Lingkungan Hidup dan Kehutanan (KLHK). (2023). Komposisi Sampah Nasional. Sistem Informasi Pengelolaan Sampah Nasional (SIPSN). Retrieved from https://sipsn.menlhk.go.id/sipsn/public/data/komposisi

Kementerian Pertanian (Kementan). (2024). *Buletin Konsumsi Pangan Tahun 2024*. Pusat Data dan Sistem Informasi Pertanian. Kementan. Retrieved from https://satudata.pertanian.go.id/assets/docs/publikasi/Buletin_Konsumsi _Smt2-2024-Gab.pdf

Kristianto, A. H., Suratman, E., Yani, A., & Restiatun, R. (2023). Interlinkage of Circular Economy in Waste Management, Environmental Quality, and Public Health in Indonesia. *International Research in Social Sciences*.

Mankiw, N. G. (2018). *Principles of Economics* (8th ed.). Cengage Learning.

Mulyani, F., Frian, A., & Abdullah, T. M. K. (2024). Circular Economy Implementation: A Case Study in Indonesia. *Jurnal Inovasi Global*.

Munawar, E., Yunardi, Y., Lederer, J., & Fellner, J. (2018). The development of landfill operation and management in Indonesia. *Journal of Material Cycles and Waste Management, 20*, 1128–1142.

Nindiya, T. M., & Kusumastuti, R. (2025). Enhancing Circular Economy Capability in Indonesian MSMEs: The Role of Sustainable Supply Chain Design in the Fashion and Cosmetics Industries. *EcoProfit: Sustainable and Environment Business*.

Niu, S., Liu, S., Deng, W., Wu, R., Cai, Y., Liao, X.-D., & Xing, S. (2022). *A sustainable and economic strategy to reduce risk antibiotic resistance genes during poultry manure bioconversion by black soldier fly Hermetia illucens larvae: Larval density adjustment. Ecotoxicology and Environmental Safety, 232*, 113294.

Noerhatini, P., Al Hakim, A. D., Setiawati, Y., Azhari, S. K., Munaf, D. R., & Azka, R. M. (2022). *Business model based on coffee husk bioconversion by black soldier fly (Hermetia illucens) and agroforestry system in Bandung Regency, West Java. Proceedings of the International Conference on Economics, Management and Accounting (ICEMAC 2021).*

Nurilma, S. 2019. *Potensi pengembangan produk kreatif furnitur plastik daur ulang berwawasan eco-design di Yogyakarta* (Doctoral dissertation, Institut Seni Indonesia Yogyakarta).

Nurjanah, P. 2024. *Peran Sektor Industri Pengolahan Dalam Perekonomian Provinsi Jawa Barat: Pendekatan Analisis Input-Output* (Bachelor's thesis, FEB UIN JAKARTA).

Octarya, Y., Yenti, N., & Mustofa, M. (2025). *Sustainable solid soap production using recycled cooking oil, ecoenzyme, and lemongrass extract.*

Odongo, V. O., Bbosa, F., Kaggwa, M., & Odhiambo, J. (2024). *Black soldier fly (BSF): A sustainable solution for protein and waste management.*

Ozili, P. K. (2021). *Circular economy, banks and other financial institutions.*

Pratisto, D. S., Karimah, R. N., & Anwar, M. (2024). *Optimalisasi minyak jelantah dan sumber daya alam atsiri menjadi produk lilin dan sabun aromaterapi yang ramah lingkungan di Karanganyar, Jawa Tengah.*

Priandika, R., Kuswanto, M., & Hidayat, T. (2021). *Sturdy and modular concept of 2-in-1 public furnitur desain using recycled plastic waste in urban parks.*

Puspitasari, F., Fathul, F., & Tantalo, S. (2014). PENGARUH DOSIS UREA DALAM AMONIASI DAUN NENAS VARIETAS Smooth cayene TERHADAP KADAR BAHAN KERING, ABU, DAN SERAT KASAR. JURNAL ILMIAH PETERNAKAN TERPADU, 2(3). https://doi.org/10.23960/jipt.v2i3.p%2525p

Salsabila, L., Lodan, K. T., & Khairina, E. (2023). Public Engagement Impact on Sustainable Waste Management in Indonesia: Examining Public Behavior. *Jurnal Administrasi Publik.*

Sasti, R. A. T., Soewardikoen, D. W., & Swasty, W. (2025). Reverse Commerce (Re-Commerce) Design for the Sale of Secondhand Ecoprint Products as an Implementation of Circular Economy in Indonesia. *Jurnal Indonesia Sosial Teknologi*, 6(1).

Shen, G., Yang, Y., Wang, W., Tao, S., Zhu, C., Min, Y., Xue, M., Ding, J., Wang, B., Wang, R., Shen, H., Li, W., Wang, X., & Russell, A. G. (2010). Emission factors of particulate matter and elemental carbon for crop residues and coals burned in typical household stoves in China. Environmental science & technology, 44(18), 7157–7162. https://doi.org/10.1021/es101313y

Shiri, A., Krafft, M., & Boubekri, N. (2019). *Plastic lumber product development using commingled plastic waste reinforced with fly ash and rubber powder.*

Shobande, O. A., Ogbeifun, L., & Tiwari, A. K. 2025. Net-zero transitions: Advancing dynamic econometric analysis of carbon tax, renewable energy, and circular economy on government actions. *Journal of Environmental Management, 378*, 124761.

Subekti, R. (2023). *A circular economy-based plastic waste management policy in Indonesia (Compared to China and EU). Yustisia Jurnal Hukum.*

Turlakova, Y. (2023). *Business transformations through the application of the circular economy concept in the context of sustainable development.*

Wijayanto, E., Azmi, N., & Damayanti, R. (2023). *Pemberdayaan ibu-ibu PKK melalui pemanfaatan minyak jelantah menjadi lilin aromaterapi untuk peningkatan ekonomi keluarga di Desa Cangkol, Sukoharjo.*

Yang-Jie, D., Xiang, F., Tao, X., Jiang, C., Zhang, T., & Zhang, Z.-J. (2022). *A full-scale black soldier fly larvae (Hermetia illucens) bioconversion system for domestic biodegradable wastes to resource. Waste Management & Research, 41*(2), 143–154.

Yuwono, A., Permana, I., Syahril, A., & Sembiring, H. B. (2022). Producing feed protein by bioconversion of domestic and industrial organic solid wastes using Black Soldier Fly (BSF) larvae. *IOP Conference Series: Earth and Environmental Science, 1001*(1). https://doi.org/10.1088/1755-1315/1001/1/012008

Yusof, Y., Yahya, S. A., & Adam, A. (2015). Novel Technology for Sustainable Pineapple Leaf Fibers Productions. Procedia CIRP, 26, 756–760. https://doi.org/10.1016/j.procir.2014.07.160

Zemanová, L. (2023). *Circular economy implementation from the perspective of enterprises and business environment barriers.*

Zhang, Q.-H., Silvaraju, S., Unadirekkul, P., Lim, N. W., Heng, C. W., Liu, M. H., & Puniamoorthy, N. (2023). *Laboratory-adapted and wild-type black soldier flies express differential plasticity in bioconversion and nutrition when reared on urban food-waste streams. Journal of the Science of Food and Agriculture.*

Zlotnik, Y. (2021). *Circular economy as a part of the organizational corporate strategy.*

Appendix

Table 4. 9 Pain Points and Solutions Matrix of BSF MSMEs

Aspects	Pain Points	Solutions
Productivity	• High variability in the quantity and quality of organic waste; often mixed contaminants (plastics, metals) so that they interfere with biological processes. • The absence of a structured procurement system results in supply fluctuations and uncertainty of long-term production planning.	• Strengthening strategic partnerships with regional administrations, waste management entities, and food industry stakeholders. • Implementation of Raw Material Quality Protocols through on-site inspections and periodic laboratory analysis. • Development of incentive schemes (e.g., profit-sharing or transportation subsidies) to enhance supplier loyalty.
Financial	• Limited production scales and infrastructural constraints contribute to high production costs. • Poor financial bookkeeping among MSMEs impedes access to formal financing, particularly bank credit.	• Implementation of transparent and standardized financial reporting systems that are compliant with the requirements of financial institutions. • Utilization of green financing instruments, agritech fintech solutions, and Public-Private Partnership (PPP) schemes. • Development of a phased investment roadmap aimed at increasing production capacity.
Process	• Production infrastructure remains rudimentary, hindering the achievement of economies of scale. • Standard Operating Procedures (SOPs) lack comprehensive documentation. • Human resource capabilities are limited, specifically regarding technical cultivation methods and quality control.	• Infrastructure modernization through investment in processing machinery, such as shredders, dryers, and bioponds. • The formulation of production Standard Operating Procedures (SOPs) and standard-based quality control protocols. • Enhancement of human resource capacity via technical training and the implementation of monitoring systems based on Key Performance Indicators (KPIs).
Support	• The minimal adoption of digital marketing and e-commerce platforms results in suboptimal market penetration. • Digital footprints and modern distribution networks remain limited. • Collaboration among business actors, academics, and corporate buyers is currently weak.	• Development of digital marketing and e-commerce training programs featuring application-oriented modules. • Establishment of regional BSF (Black Soldier Fly) clusters to strengthen collaboration, applied research, and market access. • Utilization of social media and innovation forums to expand distribution channels and enhance competitiveness.

Table 4. 10 Pain Points and Solutions Matrix for MSMEs Eco Furniture Design

Aspect	Pain Points	Solutions
Productivity	• Small-scale production remains inefficient. • Sorting and cleaning plastic waste is time-intensive. • Limited capacity and skills within human resources (HR).	• Utilization of high-capacity production machinery. • Collaboration with waste management startups. • Enhancement of HR capabilities through capacity-building programs.
Financial	• Minimal access to financing. • Production upscaling requires significant capital investment. • High logistical costs associated with transporting plastic waste.	• Implementation of standardized financial bookkeeping to facilitate access to funding. • Expansion of targeted green financing initiatives. • Sourcing raw materials from waste managers located near the production site (to reduce costs).
Process	• Raw material supply for production remains unstable. • MSMEs lack the capability to process all types of plastic. • Integration with waste management startups or waste operators is still minimal.	• Cooperation with waste managers to secure a stable supply of raw materials. • Utilization of advanced production machinery (e.g., extruder machines). • Collaborative contracts with waste management startups to acquire high-quality waste materials.
Support	• Digitalization of financial records and emission data is underutilized. • Utilization of e-commerce platforms remains low. • The lack of domestic/global standards for MSME products diminishes consumer confidence in recycled plastic products.	• Utilization of digital applications for financial recording and carbon emission tracking. • Optimization of e-commerce platforms to reach broader domestic and global markets. • Product certification and business standardization at both domestic and global levels.

Table 4. 11 Pain Points and Solutions Matrix for Eco Fashion MSMEs

Aspect	Pain Points	Solutions
Productivity	• Small-scale production remains inefficient. • Sorting and cleaning plastic waste is time-intensive. • Limited capacity and skills within human resources (HR).	• Utilization of high-capacity production machinery. • Collaboration with waste management startups. • Enhancement of HR capabilities through capacity-building programs
Financial	• Minimal access to financing. • Production upscaling requires significant capital investment. • High logistical costs associated with transporting plastic waste.	• Implementation of standardized financial bookkeeping to facilitate access to funding. • Expansion of targeted green financing initiatives. • Sourcing raw materials from waste managers located near the production site (to reduce costs).
Process	• Raw material supply for production remains unstable. • MSMEs lack the capability to process all types of plastic. • Integration with waste management startups or waste operators is still minimal.	• Cooperation with waste managers to secure a stable supply of raw materials. • Utilization of advanced production machinery (e.g., extruder machines). • Collaborative contracts with waste management startups to acquire high-quality waste materials.
Support	• Public perception regards the quality of pineapple leaf fiber weaving as inferior to other materials. • Green branding concepts remain unfamiliar to the wider public. • Digitalization of sales promotions is currently underutilized.	• Execution of educational and promotional campaigns emphasizing the competitive advantages of pineapple leaf fiber weaving. • Acquisition of quality certifications and green process verifications. • Utilization of social media and online marketplaces for sales distribution.

Table 4. 12 Pain Points and Solutions Matrix for MSMEs in UCO

Aspect	Pain Points	Solutions
Productivity	• Long sediment and oil separation time • Low production scale and inefficient practices in the used cooking oil collection process • Low public awareness leads to indiscriminate disposal of used cooking oil and limited stocks of key raw materials.	• Implementation of more efficient used cooking oil filtering technology • Provision of related facilities and infrastructure • Development of a more efficient and integrated used cooking oil collection system • Conducting campaigns that not only focus on environmental hazards but also provide incentives in the form of social compensation.
Financial	• Price competition among collectors has driven up prices for used cooking oil. • Lack of adequate financing schemes. • High logistics costs, including shipping and warehouse rental fees.	• Integrated collaboration between collectors and processors to maintain price stability • Provision of inclusive and affordable financing schemes for MSMEs • The government can provide subsidies, such as for logistics costs or the use of government facilities
Process	• The received raw materials vary in quality. • Limited capital assets, such as screening machines and product moulds, limit capacity and product variety. • Limited availability of high-value rubber-based moulds.	• Establishing standards for the trade of used cooking oil. • Provision of adequate capital goods by the government or financial institutions. • Collaboration between relevant MSMEs to design, produce, and sustainably supply unique molds.
Support	• The lack of nationally recognized product standards reduces consumer confidence in used cooking oil processed products. • The use of digital marketing is still limited, • Digitization of financial records is still low	• Improving MSME capabilities through digital marketing training and the use of e-commerce platforms • Training on digitalizing financial records for MSMEs • Assisting MSMEs in meeting product standards