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# Global Circular Economy Practice: Drivers, Barriers and Strategies for Food System in Indonesia

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**ABSTRACT**

The urgent need to overhaul food systems towards more regenerative, inclusive, and sustainable approaches has become a critical concern, particularly with the goal of providing healthy food for a global population that will exceed 9 billion by 2050 and an Indonesian population that will reach 300 million. With the current destructive agricultural framework, significant environmental damage is not the only consequence; there is also a decline in social quality within Indonesia's rural and urban communities. This study aims to design a circular economy implementation strategy formulated through SWOT analysis in order to build a sustainable food system in Indonesia. The research methods used are Systematic Literature Review (SLR), Pareto analysis, and SWOT analysis. The results of this SWOT analysis were used as recommendations to develop Indonesia's food system with a circular economy approach, similar to what has been developed at the global level This SWOT strategy shows that by leveraging existing strengths, addressing weaknesses, capitalizing on opportunities, and overcoming threats, Indonesia can develop a more sustainable and resilient food system through a circular economy approach.

## 1. INTRODUCTION

The global food system, driven by the food and beverage industry, significantly impacts sustainability, contributing to 60% of biodiversity loss, 60% of land conversion, 70% of overnutrition, and 30% of climate change. By 2050, unsustainable food production could lead to the loss of around 5 million lives annually [1]. The food and agriculture sectors have a more pronounced impact on land, water resources, employment, and economic activity than other sectors [2]. In Indonesia, energy consumption in the food and beverage sector nearly doubled between 1980 and 2015 [3].

With a projected global population of 9 billion by 2050, maintaining current food systems could cause significant environmental and social harm. Rural agriculture must shift to regenerative practices, and urban areas need to adopt healthier diets, reduce food waste, and create a nutrient cycle. This urgency is heightened by Indonesia's large population that will reach 300 million, necessitating a regenerative and sustainable food sector. This study utilizes SWOT analysis to assess the strengths, weaknesses, opportunities, and threats in implementing such strategies [4].

The cornerstone of the Circular Economy (CE) is systemic change, which starts from "rethinking" ways to extend the lifespan and life cycle of a material and product [5]. This shift requires collaboration among producers, consumers, and governments [6]. The CE paradigm aims to prevent environmental degradation while ensuring the economic and social well-being of current and future generations [7, 8]. Initially based on 3R principles (Reduce, Reuse, Recycle), the CE now includes 9R strategies (Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover energy) [8-12].

Agriculture consumes about 200 Exajoules of energy annually, with food production responsible for 30% of global energy use. The food system is also the largest land user, and over one-third of food produced is lost or wasted, wasting essential resources amid increasing food demand [13, 14].

The global food system, and the food and beverage industry behind it, is directly involved in some of the most pressing sustainability challenges, contributing to 60% of biodiversity loss, 60% of land conversion, 70% of overnutrition, and 30% of climate change [15]. The same report estimates that by 2050, around 5 million lives could be lost annually as a result of unsustainable food production processes [16].

In the United States, the food manufacturing sector was found to be the worst actor and responsible for the "highest environmental impacts" including 20% of national greenhouse gas emissions and 12% of water withdrawal [17, 18]. In places like Indonesia, the share of energy consumption in the food and beverage sector almost doubled between 1980 and 2015.

The global food system will face unprecedented pressure. It is estimated that by 2030, global population growth and the impact of climate change will increase the need for food

production by up to 50% [19]. By 2030, the food and beverage industry will collectively need 45% more energy and 30% more water for agriculture. By 2050, the global population is expected to increase further to 9.3 billion people with an increase in food demand by 60% [20].

Global climate change, population growth and food security challenges are driving the need to transition towards a more sustainable food system through a circular economy approach, which focuses on reducing waste and improving resource efficiency. While this concept has been widely applied in developed countries, its application in food systems in developing countries, particularly Indonesia, still faces various challenges and has not been empirically studied.

This study aims to identify key challenges and opportunities in the implementation of circular economy in Indonesia, evaluate the effectiveness of existing practices, and analyze the influence of national policies and local socio-economic conditions on the success of this implementation.

The research is grounded in recent literature on circular economy, particularly in the food system. A recent study by Yang et al. [21] shows that the implementation of circular economy in the food sector can reduce greenhouse gas emissions by up to 30%. On the other hand, Yadav et al. [22] highlighted challenges in organic waste management in developing countries that may hinder the effectiveness of circular economy. Based on this framework, this research will integrate SWOT and Pareto analysis to identify implementation strategies that are most relevant to the Indonesian context.

The reason for conducting this study is that a circular economy not only offers Indonesia the opportunity to reduce waste and improve the environment, but it can also become a vital element in the country's economic recovery efforts. Like governments around the world, policymakers in Indonesia are working to support the economic recovery after the COVID-19 pandemic. However, the main challenge is whether these recovery policies will reinforce the existing "business-as-usual" economic structures with their negative impacts on the environment, or whether there is an opportunity to "build back better" by optimizing the balanced benefits between the economy and the environment [23]. Since circular economy practices in Indonesia's food sector have become an inevitability, the purpose of this study is to recommend strategies for circular economy practices in Indonesia's food system based on the key drivers (strengths and opportunities) and barriers (weaknesses and threats).

## 2. RESEARCH METHODS

### 2.1 Systematic Literature Review (SLR)

To conduct a thorough literature review on the application of circular economy in food systems, a Systematic Literature Review (SLR) was conducted. This process included several steps. First, a literature search was conducted using a set of predefined keywords and phrases [24, 25], such as "circular economy food system, drivers and barriers circular economy, circular economy strategy, implementation of circular economy food system, socio-technical system for food system". Relevant literature was identified through several academic databases in Scopus. Specialized databases relevant to environmental science and food systems were also checked to ensure a comprehensive review.

The eligibility of articles included in the study was determined using the following inclusion and exclusion criteria:

- Inclusion criteria included reviewed articles, research papers and reports published within the last five years, with a focus on circular economy practices, food systems and sustainability, and research relevant to the Indonesian context or comparable regions.
- Exclusion criteria included non-peer-reviewed sources, articles published outside the last five years, and studies not directly related to circular economy or food systems.

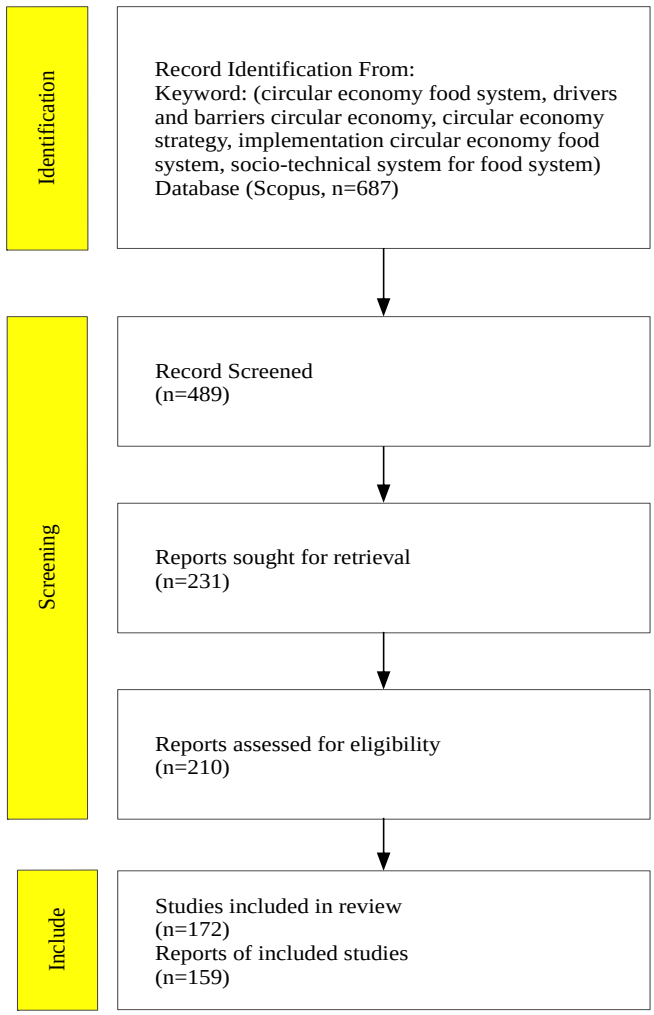


**Figure 1.** SLR

Based on Figure 1, At the identification stage in this study, a literature search was carried out using the keywords "circular economy food system, drivers and barriers circular economy, circular economy strategy, implementation of circular economy food system, socio-technical system for food system". This search was performed in the Scopus database and yielded 687 records. Next, in the screening stage, of the initial 687 records, 489 records were screened by checking the title and abstract to ensure relevance to the topic under review. Of the 489 records screened, 231 reports were identified for retraction or full text to be obtained. Of the 231 reports withdrawn, 210 reports were evaluated for eligibility by assessing the full text to ensure that they met predetermined inclusion criteria. At the inclusion stage, of the 210 reports evaluated, 172 studies were included in the final review. Of

the 172 included studies, 159 reports of these studies were included in the final review, demonstrating a rigorous and methodical screening stage to ensure only relevant studies were included in this systematic review [26, 27].

### 2.2 Pareto analysis

Pareto Analysis, grounded in the Pareto Principle (80/20 rule) [28], was employed to pinpoint the most significant factors influencing the implementation of a circular economy within Indonesia's food system. This method prioritizes issues by identifying the 20% of causes that account for 80% of the effects, thereby focusing on the most impactful barriers and opportunities [29]. Data on various challenges and prospects related to circular economy practices were systematically collected from the reviewed literature. Subsequently, a Pareto chart was created to visually depict these factors, ranked in descending order of their significance [30, 31]. This chart effectively highlighted the most critical elements requiring targeted intervention and strategic action to enhance the implementation of circular economy principles in the food system.

### 2.3 Strengths, weaknesses, opportunities and threats (SWOT) analysis

SWOT Analysis was utilized to evaluate the Strengths, Weaknesses, Opportunities, and Threats associated with implementing a circular economy in Indonesia's food system. This strategic tool facilitates a comprehensive understanding of both internal and external factors that affect the success of circular economy practices. Data for SWOT Analysis were collected through a SLR, expert interviews, and stakeholder feedback [32]. The data were categorized into Strengths (internal positive factors), Weaknesses (internal negative factors), Opportunities (external positive factors), and Threats (external negative factors), which aided in formulating targeted strategies for effective implementation [33]. To ensure validity and reliability, the study employed rigorous methods. Internal validity was maintained by cross-checking data from multiple sources and applying consistent criteria for evaluating the relevance and quality of included studies [34]. External validity was considered by evaluating the generalizability of the findings to other regions and food systems similar to Indonesia. Reliability was assured through standardized data collection and evaluation methods, involvement of independent reviewers, and resolution of discrepancies through discussions [35]. Quality assurance was further strengthened by cross-validating results with existing studies and employing statistical techniques to confirm the accuracy of the findings.

## 3. RESULTS AND DISCUSSION

### 3.1 Factor identification and categorization

The circular economy in the food system aims to reduce waste and maximize the use of resources through recycling, reuse and extending the life of food products [36, 37]. The factors that influence this system can be categorized into several main aspects. First, in the resource and raw materials category, sustainable agricultural practices that reduce the use of chemicals and maximize yields through organic methods are essential [7, 23]. The efficiency of water use in irrigation and food production as well as the use of renewable energy in the food production and distribution process are also significant factors [38]. Second, in the production and manufacturing process category, innovative food processing technologies, which reduce production waste and increase efficiency, as well as the use of environmentally friendly packaging, such as recyclable or biodegradable materials, are key aspects that need to be considered [39].

Apart from that, distribution and logistics factors also influence the circular economy in the food system. Supply chain optimization through information and communication technology can reduce waste and increase distribution efficiency [40, 41]. A decentralized and community-based distribution system can reduce carbon footprints and ensure fairer food distribution. In the consumption and reuse category, sustainable consumption patterns and food waste management are crucial factors. Consumer education about the importance of reducing food waste and choosing sustainable products is very necessary. Reusing and recycling food waste, such as compost and biogas production, can reduce environmental impact and maximize the value of each stage in the food life cycle. By identifying and categorizing these factors, the application of circular economy principles in food systems can be optimized to achieve greater sustainability.

**Table 1.** Drivers for circular economy practice in food system

| No. | Drivers | Characteristic | Stakeholders | Frequency of Mention | Percentage of Total Mentions | Country | References |
|---|---|---|---|---|---|---|---|
| 1 | Food Price Instability | Eksternal (Threats) | Farmer<br>Government<br>Trader<br>Consumer | 25 | 19.5% | Denmark | [3, 13, 14], [42-46] |
| 2 | Resource Efficiency | Internal (Strengths) | Farmer<br>Food Producer<br>Government<br>Food industry | 15 | 11.7% | Netherlands, Finlandia | [47-52] |
| 3 | New Market Opportunities | Eksternal (Opportunities) | Food Producer<br>Government<br>Consumer<br>Investors | 10 | 7.8% | Singapura | [53-55] |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | Consumer Awareness | Eksternal (Opportunities) | Consumer<br>Environmental NGO<br>Government | 12 | 9.4% | Prancis | [13, 14, 43, 56] |
| 5 | Concern for Food Waste | Internal (Strengths) | Farmer<br>Food Producer<br>Environmental NGO | 8 | 6.3% | Thailand | [40, 57, 58] |
| 6 | Climate change | Eksternal (Threats) | Farmer<br>Government<br>Researchers and Scientists | 30 | 23.4% | Sweden | [14, 37, 59-64] |
| 7 | Scarcity of Natural Resources | Eksternal (Threats) | Farmer<br>Government<br>Environmental NGO | 20 | 15.6% | Norway | [54, 55, 65, 66] |
| 8 | Food security | Internal (Strengths) | Farmer<br>Food Producer<br>Government<br>Consumer<br>Humanitarian NGO<br>International Organization | 18 | 14.1% | Germany | [45, 57, 58, 67-72] |

Based on Table 1, food price instability is an external threat influenced by factors such as climate change, natural disasters and political unrest, with 25 mentions from Denmark [3, 13, 14, 42-46].

Meanwhile, resource efficiency, which includes optimal use of water, energy, land and fertilizer, was identified as an internal strength, with 15 mentions from the Netherlands and Finland [47-52, 72].

New market opportunities, such as demand for organic and sustainable products, were identified as external opportunities with 10 mentions from Singapore [53-55, 73].

Efforts to reduce food waste and recycle food scraps are considered an internal strength with 8 mentions from Thailand [40, 57, 58].

Climate change, which affects food production through increasing the frequency of natural disasters, was identified as an external threat with 30 mentions from Sweden [14, 37, 59-64].

Scarcity of natural resources due to overexploitation and increased demand was identified as an external threat, with 20 mentions from Norway [53-55, 65, 66].

Lastly, food security, which includes consistent access to sufficient, safe, and nutritious food, was identified as an internal strength with 18 mentions from Germany [45, 57, 58, 67-72]. The visualization of the Main Driver can be seen in Figure 2 below.

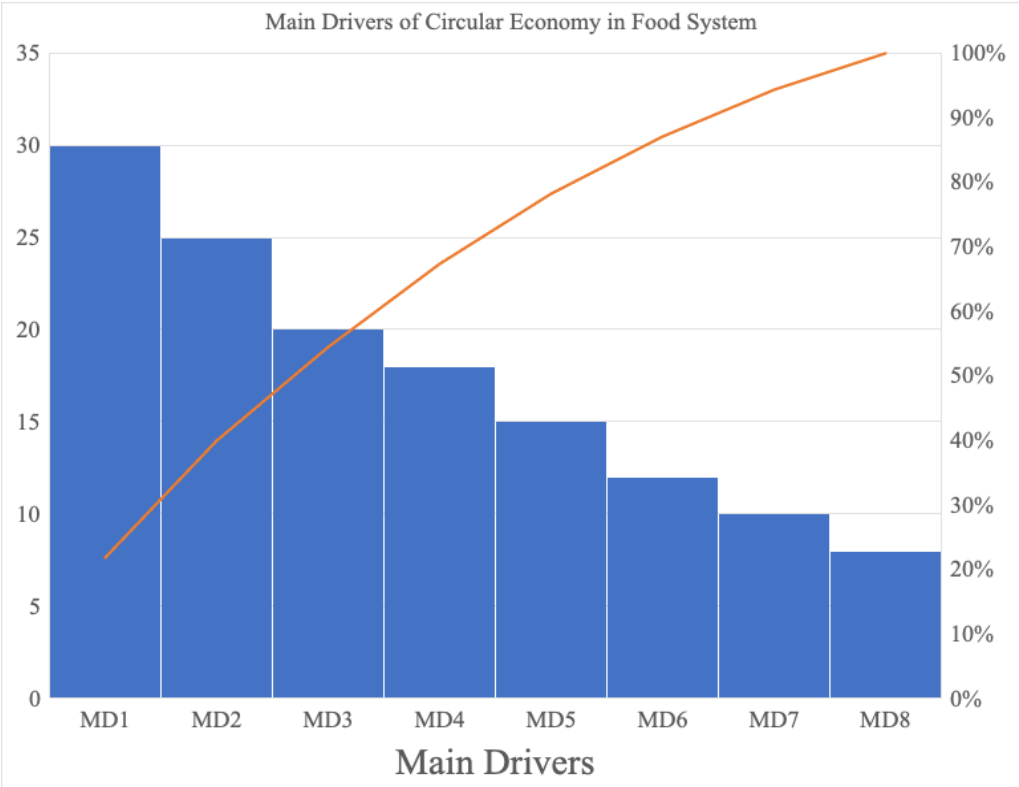


**Figure 2.** Pareto chart for main drivers of circular economy practice in food system

**Table 2.** Coding of main drivers

| Main Drivers | | Definition |
|---|---|---|
| MD1 | Climate change | Changes in global weather and climate patterns that have a significant impact on food production, such as increasing the frequency and intensity of natural disasters, droughts and floods |
| MD2 | Food Price Instability | Fluctuations in global food commodity prices are influenced by factors such as climate change, natural disasters, political turmoil, and supply-demand imbalances |
| MD3 | Scarcity of Natural Resources | Natural resource scarcity refers to conditions in which certain natural resources become increasingly scarce or difficult to access due to overexploitation, increased demand, or a decline in the quality of the resource |
| MD4 | Food security | Food security encompasses the ability of a country, region, or individual to consistently access sufficient, safe, and nutritious food |
| MD5 | Resource Efficiency | Optimal use of natural resources (water, energy, land, fertilizer) and minimization of resource losses throughout the food supply chain |
| MD6 | Consumer Awareness | Increased consumer understanding and awareness of the social and environmental impacts of food choices |
| MD7 | New Market Opportunities | There is emerging consumer demand for more sustainable food products and services, such as organic, local, fair trade and minimal packaging. |
| MD8 | Concern for Food Waste | Efforts to reduce food waste, recycle leftover food, and utilize it as a resource |

The definition of each main drivers can be seen in Table 2 which explains that global food price fluctuations are often triggered by various external factors, such as climate change, natural disasters, political instability, and supply-demand imbalances. Previous studies show that climate change has a direct impact on food price volatility by disrupting food production and distribution [3, 43, 44, 46]. However, Lehtokunnas et al. [15] highlight that although food price volatility can be a major threat to farmers and consumers, appropriate government policies can mitigate its negative impacts [46]. This discrepancy suggests that further research is needed to understand how food price volatility can be managed more effectively, especially in the context of Indonesia which is vulnerable to natural disasters.

Optimal use of resources along the food supply chain can increase efficiency and reduce waste, which are considered strengths in the context of a circular economy. Bianchi and Cordella [47] and Barros et al. [74] emphasize the importance of resource efficiency in reducing the environmental impact of food production. However, Norton et al. [49] stated that the biggest challenge in implementing resource efficiency is the lack of adoption of advanced technologies in several countries, including Indonesia. This shows that although resource efficiency offers great opportunities, its implementation requires strong technological support and proactive government policies to encourage adoption at the industry level.

Consumer awareness of the social and environmental impacts of food choices is also an external opportunity, with 12 mentions from France [13, 14, 43, 56]. There is a growing demand from consumers for more sustainable food products, such as organic, local, fair trade, and minimalist packaging. Barros et al. [74] and Broccardo et al. [54] show that these new market opportunities create economic incentives for food producers to adopt more environmentally friendly practices. However, Mehmood et al. [53] emphasized that despite the promising market opportunity, a major challenge lies in the higher price of sustainable products, which may deter consumers in developing countries like Indonesia from switching to them. This mismatch indicates that further research is needed to identify the best way to bridge the gap between consumer demand for sustainability and affordability in the Indonesian market.

Efforts to reduce food waste and utilize it as a resource are one of the strengths in implementing a circular economy. Klingbeil and Byiringiro [58] and Lavelli [40] show that effective food waste management can reduce environmental impacts and increase resource efficiency. However, Kongs et al. [55] note that this implementation still faces major challenges, especially in developing countries like Indonesia, where infrastructure for recycling food waste is still very limited. This difference in results suggests that, while there is great potential to reduce food waste, a more holistic approach supported by adequate policy and infrastructure investment is needed to ensure success in a country like Indonesia.

Climate change has significant impacts on food production, such as increasing the frequency and intensity of natural disasters. Researches by Azimli and Doni [62] and Johannsdottir [64] found that increasing global temperatures and changing weather patterns have led to a decline in agricultural yields in some regions. On the other hand, Maja & Ayano showed that adaptation to climate change through advanced agricultural technologies can mitigate these negative impacts [63]. However, in the Indonesian context, the application of these technologies is still constrained by limited infrastructure and access to finance for smallholder farmers. Therefore, further research is needed to identify effective strategies in addressing the challenges of climate change, especially those adapted to local conditions in Indonesia.

Natural resource scarcity is becoming an increasingly urgent threat amidst increasing demand and declining resource quality. Broccardo et al. [54] and Hina et al. [66] found that overexploitation and increasing demand have led to a decline in the availability of critical resources such as water and soil. On the other hand, Wang et al. [57] emphasized that this scarcity can be addressed by more efficient and innovative resource management, such as through sustainable agricultural practices and water management technologies. However, in the Indonesian context, limited access to technology and financial resources hinder efforts to effectively manage this scarcity. This points to the need for further research to explore solutions that are locally appropriate and that can be adopted by smallholder farmers in Indonesia. Natural resource scarcity is becoming an increasingly urgent threat amidst increasing demand and declining resource quality. Broccardo et al. [54] and Hina et al. [66] found that overexploitation and increasing demand have led to a decline in the availability of critical resources such as water and soil.

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the Indonesian context, limited access to technology and financial resources hinder efforts to effectively manage this scarcity. This points to the need for further research to explore solutions that are locally appropriate and that can be adopted by smallholder farmers in Indonesia.

Food security encompasses the ability of a country, region or individual to consistently access sufficient, safe and nutritious food. Alareeni et al. [76] and Vågsholm et al. [69] emphasize the importance of food security as a key factor in societal well-being. However, Boon and Anuga [74] point out that food security is often disrupted by external factors such as climate change, political instability, and food price fluctuations. In Indonesia, food security challenges are becoming increasingly complex with the increasing population and changing consumption patterns. Therefore, further research is needed to develop strategies that can improve food security in Indonesia, taking into account the specific challenges the country faces.

**Table 3.** Barriers for circular economy practice in food system

| No. | Barriers | Characteristic | Stakeholders | Frequency of Mention | Percentage of Total Mentions | Country | References |
|---|---|---|---|---|---|---|---|
| 1 | Infrastructure Limitations | Internal (Weakness) | Government (Department of Transport, Department of City Planning), Construction Companies, Infrastructure Operators (Road Managers, Airports, Ports), Communities | 20 | 14.4% | Indonesia, Filipina, Malaysia, Amerika Serikat, China, India, Australia, Afrika Selatan | [53, 55, 65, 77-81] |
| 2 | Policies and Regulations | Eksternal (Opportunities) | Government (Environmental Agency, Ministry of Agriculture, Ministry of Trade, Regulatory Agency), Business Associations, Universities | 25 | 18% | Vietnam, Thailand, Laos, Amerika Serikat, Brasil | [82-94] |
| 3 | Implementation Costs | Internal (Weakness) | Company Management, Finance Department, Shareholders, Government (through incentives or financial support) | 22 | 15.8% | Kamboja, Myanmar, Timor Leste, Amerika Serikat, China, Australia | [95-101] |
| 4 | Awareness and Education | Internal (Strengths) | Universities, Environmental NGOs, Community Organizations, Media, Consumer Associations, Government (through educational campaigns) | 18 | 12.9% | Singapura, Brunei, Vietnam, Brasil | [15, 65, 102-108] |
| 5 | Changes in Culture and Consumer Habits | Eksternal (Threats) | Industry Associations, NGOs, Universities, Community Organizations, Media, Consumer Associations, Government (through outreach campaigns) | 15 | 10.8% | Malaysia, Thailand, Filipina | [109-112] |
| 6 | Supply Chain Complexity | Eksternal (Threats) | Manufacturers, Distributors, Retailers, Logistics (Delivery Companies, Warehouses), Government (through supply chain policies) | 30 | 21.6% | Indonesia, Vietnam, Thailand | [113-117] |
| 7 | Dependence on Conventional Business Models | Internal (Strengths) | Business Owners, Company Management, Shareholders, Industry, Government (through incentives or regulations for business innovation) | 12 | 8.6% | Laos, Kamboja, Timor Leste | [44, 118-120] |
| 8 | Technological Challenges | Eksternal (Opportunities) | Higher Education (Department of Engineering, Technology and Computer Science), Technology Providers, Industry Associations, Government (through research and development programs) | 17 | 12.2% | Myanmar, Filipina, Brunei, Brasil | [50, 56, 121] |

Some research on barriers in other countries has been summarized in Table 3 with a visualization of the priorities that are the main barriers shown in Figure 3. The state of the main obstacles to implementing a circular economy shows that there are various challenges that must be faced. Infrastructure limitations are one of the significant obstacles, related to deficiencies in the necessary networks and facilities, involving the government, construction companies and infrastructure

operators, which was mentioned 20 times in various countries including Indonesia and the United States [53, 55, 65, 77-81]. Unsupportive policies and regulations are also a major obstacle, identified 25 times in Vietnam, Thailand, and Brazil, involving environmental agencies and business associations [82-94].

Implementation costs associated with initial investments in new technology and infrastructure are an internal barrier facing corporate management and governments, mentioned 22 times in countries such as Cambodia and China [95-101]. Lack of public awareness and education about circular economy practices is also an obstacle, involving universities, NGOs and the media, with 18 mentions in Singapore and Brazil [15, 65, 102-108]. Changes in consumer culture and habits are an external challenge, involving industry associations and government, mentioned 15 times in Malaysia and the Philippines [64, 112-116].

Supply chain complexity hinders the efficient implementation of a circular economy, found 30 times in Indonesia and Thailand, involving producers and the government [113-117], conventional business models hinders the shift to circular business models, involving business owners and government, mentioned 12 times in Laos and Timor Leste [44, 20, 50, 69, 118-120]. Finally, technological challenges are external barriers, involving higher education and technology providers, mentioned 17 times in Myanmar and Brazil [50, 101, 121]. This analysis highlights how important collaboration between various stakeholders is to overcome these obstacles and successfully implement a circular economy.

The definition of each main barrier is presented in Table 4, which explain that although the main barriers to implementing a circular economy, such as limited infrastructure, unsupportive policies, and high implementation costs, are often perceived as significant obstacles, some countries have shown that these barriers can be overcome with the right strategies [42, 101, 122]. Collaborative efforts between governments, companies, and educational institutions in countries such as Indonesia and Brazil have successfully addressed some of these issues, demonstrating that with supportive policies, technological innovation, and increased public awareness, circular economy implementation can be achieved . However, these challenges remain major obstacles in many countries, including the United States and developing countries. Infrastructure limitations, unsupportive policies, and high costs continue to be significant barriers, even with collaborative efforts [123]. This suggests that, despite progress, a more in-depth and systematic approach is needed to effectively address these issues. This analysis highlights that while there is potential for improvement, these challenges still require attention and more comprehensive solutions to achieve successful circular economy implementation.

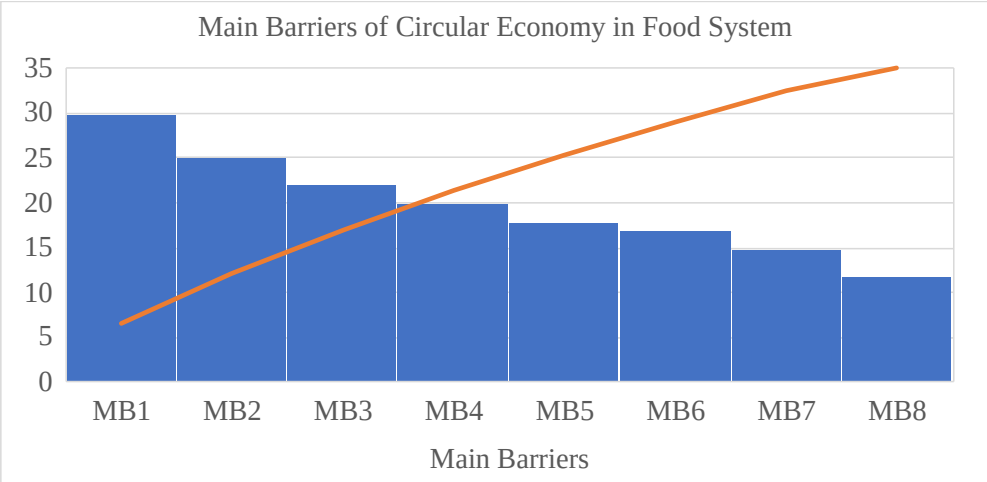


**Figure 3.** Pareto chart for main barriers of circular economy practice in food system

**Table 4.** Coding of main barriers

| | Main Barrier | Definition |
|---|---|---|
| MB1 | Supply Chain Complexity | Difficulty in managing long, diversified and complex supply chains in a sustainable and efficient manners |
| MB2 | Policies and Regulations | Barriers resulting from government regulations or policies that do not support or even hinder the adoption of circular practices |
| MB3 | Implementation Costs | Costs associated with implementing circular economy practices, including initial investments in new technology and infrastructure |
| MB4 | Infrastructure Limitations | Physical constraints or deficiencies in the networks and facilities required to support circular economy practices |
| MB5 | Awareness and Education | Lack of public knowledge and understanding of the importance and ways of implementing circular economy practices |
| MB6 | Technological Challenges | Constraints stem from limitations or lack of progress in the technology required to support circular practices |
| MB7 | Changes in Culture and Consumer Habits | Obstacles stem from the difficulty of changing consumer behavior and habits that do not support circular principles |
| MB8 | Dependence on Conventional Business Models | Barriers arising from the inability or inadequacy in moving away from unsustainable traditional business models |

**Table 5.** Strategies for circular economy practice in food system

| | Strategies | Stakeholders | Frequency of Mention | Percentage of Total Mentions | Country | References |
|---|---|---|---|---|---|---|
| **S1** | Strategy SO (Strengths-Opportunities) | Government, Farmers, Food processing industry, Universities, Research institutions, Environmental organizations, Local government | 7 | 5% | Netherlands | [3, 13, 44, 124-126] |
| **S2** | Strategy WO (Weaknesses-Opportunities) | Government, Farmers, Food processing industry, Universities, Research institutions, Environmental organizations, Local government | 6 | 4.3% | | [5, 8, 72, 127-129] |
| **S3** | Strategy SO (Strengths-Opportunities) | Farmers, Government, Universities, Research institutions, Environmental organizations, Local government | 8 | 5.8% | Denmark | [99, 130-133] |
| **S4** | Strategy WO (Weaknesses-Opportunities) | Consumers, Government, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 9 | 6.5% | | [57, 120, 134, 135] |
| **S5** | Strategy SO (Strengths-Opportunities) | Government, Farmers, Food processing industry, Universities, Research institutions, Environmental organizations, Local government | 8 | 5.8% | Sweden | [2, 136, 137] |
| **S6** | Strategy WO (Weaknesses-Opportunities) | Government, Consumers, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 6 | 4.3% | | [5, 8, 72, 129, 137, 138] |
| **S7** | Strategy SO (Strengths-Opportunities) | Government, Consumers, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 5 | 3.6% | Singapore | [74, 139-141] |
| **S8** | Strategy WO (Weaknesses-Opportunities) | Government, Consumers, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 7 | 5% | | [76, 142-144] |
| **S9** | Strategy SO (Strengths-Opportunities) | Government, Consumers, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 7 | 5% | Thailand | [7, 8, 12, 145, 146] |
| **S10** | Strategy WO (Weaknesses-Opportunities) | Government, Consumers, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 6 | 4.3% | | [8-12, 56] |
| **S11** | Strategy SO (Strengths-Opportunities) | Government, Consumers, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 7 | 5% | Malaysia | [52, 147] |
| **S12** | Strategy WO (Weaknesses-Opportunities) | Consumers, Government, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 8 | 5.8% | | [11, 101, 148-150] |
| **S13** | Strategy SO (Strengths-Opportunities) | Farmers, Government, Food processing industry, Universities, Research institutions, Environmental organizations, Local government | 7 | 5% | South Africa | [3, 44, 57, 114, 151, 152] |
| **S14** | Strategy WO (Weaknesses-Opportunities) | Government, Farmers, Food processing industry, Universities, Research institutions, Environmental organizations, Local government | 6 | 4.3% | | [125, 126, 153, 154] |
| **S15** | Strategy SO (Strengths-Opportunities) | Farmers, Government, Food processing industry, Universities, Research institutions, Environmental organizations, Local government | 7 | 5% | Kenya | [155-161] |
| **S16** | Strategy WO (Weaknesses-Opportunities) | Government, Farmers, Consumers, Food processing industry, Universities, Research institutions, Regional government | 5 | 3.6% | | [52, 58, 103, 150, 162] |
| **S17** | Strategy SO (Strengths-Opportunities) | Government, Farmers, Food processing industry, Universities, Research institutions, Environmental organizations, Local government | 8 | 5.8% | Nigeria | [125, 126, 153, 163] |

| | | | | | | |
|---|---|---|---|---|---|---|
| **S18** | Strategy WO (Weaknesses-Opportunities) | Government, Consumers, Food processing industry, Environmental organizations, Universities, Research institutions, Local government | 6 | 4.3% | | [14, 40, 79, 94] |
| **S19** | Strategy SO (Strengths-Opportunities) | Government, Farmers, Food processing industry, Universities, Research institutions, Environmental organizations, Local government | 7 | 5% | Ghana | [42, 53, 164] |
| **S20** | Strategy WO (Weaknesses-Opportunities) | Government, Farmers, Consumers, Food processing industry, Universities, Research institutions, Regional government | 6 | 4.3% | | [20, 69, 119, 165, 166] |

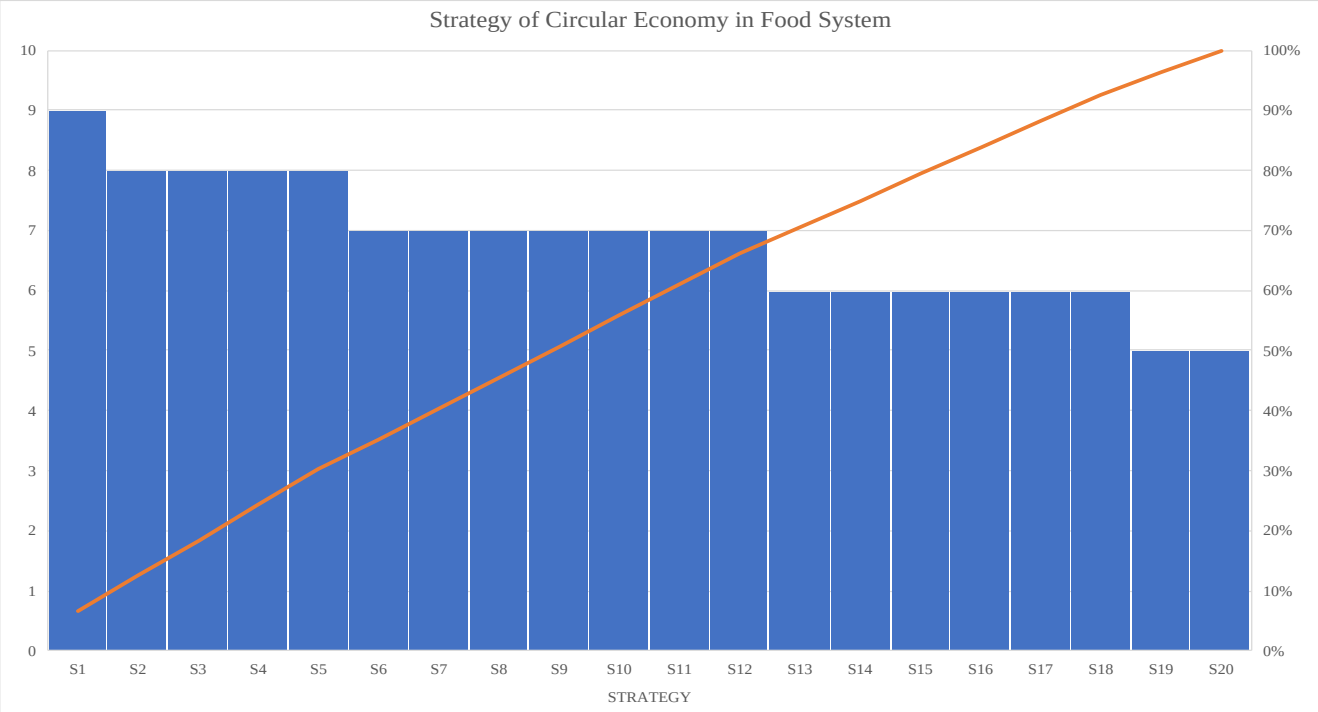


**Figure 4.** Pareto chart for main strategies of circular economy practice in food system

**Table 6.** Coding of main strategies

| Coding | Definition |
|---|---|
| **S1** | Promotion of more sustainable consumption patterns and reduction of food waste. |
| **S2** | Implementation of a sustainable agricultural model with a focus on organic farming practices and increasing resource efficiency. |
| **S3** | Use of green technology in food production and organic farming practices. |
| **S4** | Public awareness campaign about the importance of sustainable food consumption and reducing food waste. |
| **S5** | Increased investment in sustainable agriculture and green technology to increase productivity and sustainability. |
| **S6** | Development of sustainable agricultural systems by utilizing advanced technology and organic farming practices. |
| **S7** | Use of green technology and innovation in waste processing to produce renewable energy. |
| **S8** | Initiatives to increase the efficiency of resource use in agriculture and food production. |
| **S9** | Increased investment in modern agricultural technology to increase production efficiency and reduce environmental impact. |
| **S10** | Implementation of sustainable agricultural practices, including organic farming and green fertilization, to increase soil fertility and reduce pesticide use. |
| **S11** | Promotion of organic farming practices and increased access to green technologies for farmers. |
| **S12** | Development of policies and regulations that support sustainable agricultural practices and the use of green technology. |
| **S13** | Food waste recycling initiatives and development of waste processing technology to produce alternative energy and fuel. |
| **S14** | Encourage community participation in food waste recycling programs and reuse of leftovers. |
| **S15** | Encourage technological innovation in the food supply chain to reduce waste and minimize food losses. |
| **S16** | Development of education and training programs for farmers on sustainable agricultural practices. |
| **S17** | Encourage community participation in food waste recycling programs and reuse of unused food ingredients. |
| **S18** | Initiative to strengthen local food supply chains and support local food producers. |
| **S19** | Development of vertical and hydroponic farming systems to increase plant productivity in urban environments. |
| **S20** | Strengthening infrastructure to facilitate food distribution from farmers to local and national markets. |

### 3.2 SWOT analysis

Based on Table 5, it has been shown that several strategies related to the circular economy food system have been implemented and 20 types of strategies have been taken, which are processed with Pareto to display the main strategies as in Figure 4. The definitions of strategy 1 (S1) to strategy 20 (S20) are explained in Table 6.

To improve sustainability in agriculture and food production systems, various strategies have been proposed and supported by past research. S1, which focuses on promoting more sustainable consumption patterns and reducing food waste, is supported by research such as that conducted by Broccardo et al. [54], which shows that changes in consumer behavior can create economic incentives for producers to adopt greener practices. Nonetheless, Mehmood et al. [53] highlight the challenge of higher prices of sustainable products in developing countries, which may hinder the transition to such products.

S2 and S6 focus on the application of sustainable farming models and the use of advanced technologies and organic farming practices, supported by research from Lazarevic et al. [82], which show that the development of more efficient and environmentally friendly farming systems can reduce negative environmental impacts and improve resource efficiency. However, challenges related to costs and changes to existing systems may limit the widespread adoption of these models, as noted by Jonek-Kowalska et al. [87] and Diéguez-Santana et al. [93]. S3 and S7, which emphasize the use of green technologies in food production and waste processing to generate renewable energy, are supported by research from Huang et al. [167] and Jagaba et al. [107]. This research shows that green technologies can significantly reduce the environmental impact of food production and waste management. However, key challenges involve the need for large initial investments and supporting infrastructure, as highlighted by Rizos et al. [78] and Mehmood et al. [53]. S4 and S14, which focus on public awareness campaigns and community participation in food waste recycling, are supported by research from Neves and Marques [65] and Kalmykova et al. [103]. These studies emphasize the importance of raising public awareness and community engagement to achieve sustainability goals. However, challenges in reaching a wide audience and ensuring active participation may limit the effectiveness of these strategies, as noted by van Loon et al. [104] and Silva et al. [106].

S5 and S12, which include increasing investment in green technologies and developing policies that support sustainable agricultural practices, are supported by research from Corvellec et al. [98] and Philips [88]. This research shows that investments and supportive policies can improve sustainability and efficiency in agriculture. However, challenges related to the allocation of funds and consistent application of policies can hinder effective implementation, as highlighted by Thippo et al. [96] and D'amato et al. [101].

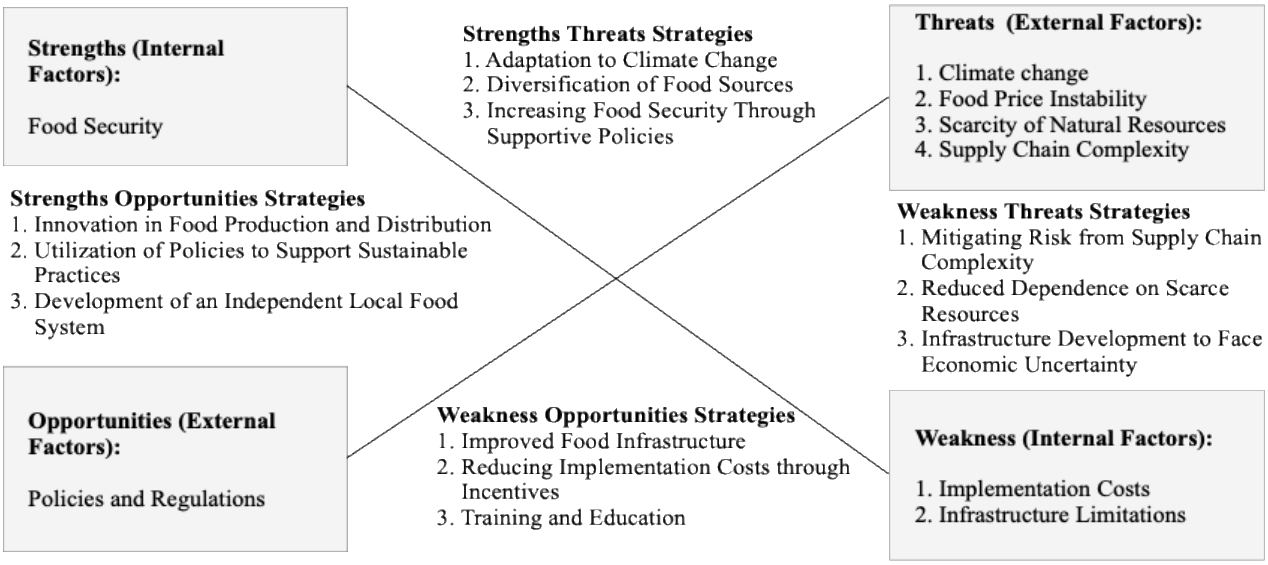


**Figure 5.** SWOT analysis: Strategies of circular economy practice in food system

3.2.1 Internal and external factors

The SWOT analysis identifies key internal and external factors affecting food security, categorized into strengths, weaknesses, opportunities, and threats. The SWOT diagram of this research is shown in Figure 5 which explains that:

a) Strengths (Internal Factors):

Food Security: This indicates robust systems and processes ensuring consistent food availability and access. It suggests effective agricultural practices, reliable supply chains, and good resource management, contributing to stability and resilience in food supply.

b) Weaknesses (Internal Factors):

- Implementation Costs: High costs related to the adoption of new technologies or processes can be a significant internal challenge. These costs include financial investments in infrastructure upgrades, training, and ongoing maintenance.
- Infrastructure Limitations: Inadequate or outdated infrastructure can severely impact the efficiency of food supply chains. Weak infrastructure may lead to increased operational costs, delays, and reduced capacity to respond to demand fluctuations.

c) Opportunities (External Factors):

Policies and Regulations: Supportive policies and regulations offer opportunities for growth and enhancement. Government incentives, subsidies, and favorable regulatory environments can foster innovation and improve operational efficiency. Compliance with new regulations can also open new markets and enhance resilience.

d) Threats (External Factors):

- Climate Change: Changes in climate pose significant risks by affecting agricultural productivity and disrupting supply chains. Extreme weather events and unpredictable climate patterns can threaten food

production and distribution.

- Food Price Instability: Volatile food prices create uncertainty for producers and consumers alike. Price fluctuations can be driven by various factors including market dynamics, economic conditions, and policy changes.
- Scarcity of Natural Resources: Limited availability of critical resources like water, arable land, and energy can constrain production and increase competition. This scarcity can lead to higher costs and reduced production capacity.
- Supply Chain Complexity: Increasing complexity in global supply chains can introduce vulnerabilities. Managing these complex networks requires advanced strategies and coordination to mitigate risks and ensure operational continuity.

3.2.2 SWOT strategy

a) SO (Strengths-Opportunities) strategy.
*Leveraging Food Security with Favorable Policies and Regulations*
Organizations can leverage their strong food security systems by aligning favorable policies and regulations to improve sustainable practices and market access. Strengthening food security through supportive policies can increase resilience to external shocks and market expansion. Research by Rubio-Andrés et al. [168], Vågsholm et al. [67] and Rodríguez-Espíndola et al. [120] emphasize the importance of strong supply chain management to leverage operational strengths in complex environments. Similarly, Krishnan et al. [135] highlight the role of policy in facilitating sustainable practices and improving knowledge transfer in food supply chains.

b) WO strategy (Weakness-Opportunity).
*Overcoming Infrastructure Limitations with Policy Support and Technological Innovation*
Organizations must strive to overcome infrastructure limitations by utilizing supportive policies and adopting new technologies. Investments in modern infrastructure and technological advances can reduce weaknesses and improve operational efficiency. Valdez et al. [169] show that implementing business continuity management and technology solutions can significantly reduce recovery times and increase resilience. Alareeni et al. [76] also stated that technological innovation can support sustainable practices and reduce supply chain complexity.

c) ST (Strength-Threat) strategy.
*Leveraging Food Security to Mitigate Climate Change and Resource Scarcity*
Organizations can leverage their strengths in food security to develop strategies that mitigate the impacts of climate change and resource scarcity. By focusing on sustainable farming practices and efficient resource management, they can reduce vulnerability to external threats. The studies of Ruokamo et al. [170] and Sharma et al. [171] highlight the need for strategic management of supply chain complexity to counter environmental and resource-related threats. Implementing sustainable practices can increase resilience and long-term survival.

d) WT (Weakness-Threat) strategy.
*Improving Infrastructure and Reducing Implementation Costs to Combat Climate Change and Price Volatility*
To overcome internal weaknesses and external threats, organizations must focus on improving infrastructure and reducing implementation costs. This can be achieved through strategic investments and cost-effective technology solutions, which help reduce the adverse impacts of climate change and price volatility. Research by Yang et al. [21] and Rehman et al. [172] underscore the importance of strategic investments in infrastructure and business continuity planning to increase supply chain resilience and reduce vulnerability to disruption.

The SWOT analysis reveals several key strategies for implementing circular economy practices in Indonesia's food system. One prominent strategy is the SO (Strengths-Opportunities) strategy, namely 'Leveraging Food Security with Supportive Policies and Regulations'. This strategy focuses on leveraging the strengths and opportunities that exist in the food system to support the implementation of a circular economy.

Strengths in this context include Indonesia's current policies that are oriented towards food self-sufficiency and national food security. Policy documents such as the National Medium-Term Development Plan (RPJMN 2024-2025) and the Priority Program for Food Security and Agricultural Extension reflect the government's commitment to improving food security through various policies and regulations. This SO strategy aims to leverage these policies by integrating circular economy principles into existing food policies, thereby promoting resource efficiency, waste reduction, and sustainability of the food system [23].

The strategic recommendations found in this study strongly support the achievement of Indonesia's Vision 2045 as a Sovereign, Advanced, and Sustainable Archipelago Nation. The strategies align with the realization of Mission 2: Economic Transformation and Mission 5: Social, Cultural, and Ecological Resilience, as outlined in policy document of Indonesia's National Long-Term Development Plan (RPJPN 2025-2045). The RPJPN 2025-2045 document is designed as a follow-up to the achievements of the National Medium-Term Development Plan (RPJMN 2020-2024), which was developed by Indonesia's Ministry of National Development Planning.

However, implementing this strategy is not without challenges. Specific barriers identified in the SWOT analysis include limited waste management infrastructure and emerging technologies in circular economy practices. For example, efficient organic waste management and advanced recycling technologies have not been fully implemented in all regions, especially in rural and remote areas. In addition, lack of coordination between government agencies and relevant stakeholders can also hinder effective implementation.

Based on the results of a study conducted by Indonesia's Ministry of National Development Planning in 2021, the country's food system managed under a circular economy scenario is predicted to have a positive impact on the three dimensions of sustainable development (social, economic, and environmental) by 2030. The social dimension is indicated by the creation of 2.4 million net jobs, predominantly for women. The economic dimension is identified by a net economic

increase of USD 26.3 billion and household savings of USD 177 per year. The environmental dimension is reflected in a 52% reduction in food loss and waste (FLW), a reduction of 59 million tons of CO2e emissions, and a saving of 4 billion cubic meters of water. However, to achieve these targets, Indonesia still faces several challenges, including difficulties in changing the culture and habits of businesses and consumers, as well as a lack of infrastructure, capital, and best practices [23].

Contextual factors that make this barrier particularly pronounced in Indonesia include uneven levels of infrastructure development, challenges in procuring appropriate technology, and differences in capacity and understanding across regions. In addition, barriers to adequate human resources and training to implement circular economy practices also contribute to these difficulties. To overcome these challenges, a holistic approach is needed that includes improving infrastructure, training, and strengthening coordination between agencies and stakeholders in order to create a more sustainable and circular economy-based food system.

## 4. CONCLUSIONS

The SLR analysis was conducted to identify various driving factors, barriers, and implementation strategies for a sustainable global food system using a circular economy approach. The resulting data was then analyzed using the Pareto analysis method to determine the ranking of the main drivers, key barriers, and primary strategies. The results of the Pareto analysis were then incorporated into the SWOT conceptual framework. The results of this SWOT analysis were used as recommendations to develop Indonesia's food system with a circular economy approach, similar to what has been developed at the global level. This SWOT analysis offers various key strategies recommended to overcome challenges and capitalize on opportunities in Indonesia. Overall, this SWOT strategy shows that by leveraging existing strengths, overcoming weaknesses, taking advantage of opportunities, and addressing threats, Indonesia can develop a more sustainable and resilient food system with a circular economy approach. The results of this study need to be followed by field research, involving confirmation and verification efforts through surveys, observations, or interviews regarding the recommended strategies. This is particularly important given that the existing conditions (social, economic, and environmental) in Indonesia may differ slightly from those at the global level.

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