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PRODUCTIVITY MEASUREMENT MODEL AT *PT PANGAN BAROKAH ABADI* USING THE GREEN PRODUCTIVITY APPROACH AND GREEN VALUE STREAM MAPPING

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ABSTRACT. While the traditional food industry holds significant potential, small and medium enterprises (SMEs) continue to struggle with productivity and sustainability challenges. This study develops a productivity measurement model for *PT Pangan Barokah Abadi*, a traditional Javanese *rambak* crackers (*kerupuk rambak* Jawa) producer, by integrating Green Productivity (GP) approach with Green Value Stream Mapping (GVSM). Facing high anergy consumption, emission, and waste generation, the enterprise requires a strategy that balance economic efficiency with environmental performance. GVSM was employed to map value stream across five critical dimensions: energy, water, solid waste, logistics, and emission. Additionally, the Analytical Hierarchy Process (AHP) was utilized to systematically determine and weight green productivity criteria. The resulting model incorporates three core components: the Economic Productivity Index (EPI), the Environmental Productivity Index (EnPI), and the Green Productivity Index (GPI). This framework provides a robust quantitative assessment of operational sustainability and serves as a strategic decision-support tool. The primary contribution of this work is the development of a three-tiered indexing system (EPI, EnPI, and GPI) that translates complex environmental waste data into actionable strategic insights for resource-constrained SMEs.

INTRODUCTION

According to a 2023 World Bank report, Small and Medium Enterprises (SMEs) account for over 90% of business units worldwide (World Bank, 2019). Despite their important role, SMEs often face difficulties in increasing productivity without adversely impacting the environment. This challenge is becoming increasingly urgent as environmental regulations tighten, and consumer preferences for environmental products increase. friendly product growth (Nugraha *et al.*, 2025). In Indonesia, SMEs significantly contribute to national economic growth. According to a report by the Ministry of Cooperatives and Small and Medium Enterprises (2023), this sector accounts for approximately 60.5% of the Gross Domestic Product (GDP). It is one of the primary sources of national employment *(Direktur Jendral Pembendaharaan, 2023*). The traditional food industry is an SME sector with great potential but still faces productivity challenges (Xue *et al*., 2023; Tsiapa *et al*., 2025). Most businesses in this sector still rely on inefficient manual production methods, which reduce productivity and cause environmental issues, such as waste and suboptimal energy use (Berlec *et al*., 2024).

PT Pangan Barokah Abadi is an SME that produces traditional snacks in the form of *rambak* crackers (*kerupuk rambak*), located in the Gunung Putri District, Bogor, West Java. The main ingredients are sago flour, rice flour, and dried shrimp. The product is marketed under the brand name *Kerupuk Rambak Jawa*. The company produces approximately 15,600 kg of ready-to-eat products annually, with distribution primarily within the Greater Jakarta (*Jabodetabek*) area. The company strives to increase productivity to enhance its competitiveness and business development (Tsiapa *et al*., 2025). Productivity is the ratio of the total output in a given period to the total input used in the same period

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(Van *et al*., 2024). There are two main aspects of productivity: efficiency and effectiveness. Efficiency relates to the extent to which inputs are used optimally, whereas effectiveness refers to the degree to which objectives or expected results are achieved (Xue *et al*., 2023; Ayuka *et al*., 2025).

PT Pangan Barokah Abadi's efforts to manage productivity focus on optimizing resource utilization and minimizing waste. One approach that can be applied is green productivity (Muñoz-Villamizar *et al*., 2019; Rahko *et al*., 2024). This concept offers solutions to improve production process efficiency while reducing negative environmental impacts (Faulkner *et al*., 2014; Jamil *et al*., 2020). According to the Asian Productivity Organization (APO, 2019), green productivity is an approach to simultaneously improve business efficiency and environmental performance to support social and economic development. Applying this concept to SMEs is appropriate because the analysis is conducted across all stages of input, process, and output (Xue *et al*., 2023). This concept provides solutions to minimize adverse environmental impacts, which can ultimately reduce operational costs.

The green productivity strategy focuses on improving resource efficiency, particularly electricity, liquefied petroleum gas (LPG), and firewood, as well as controlling carbon emissions from steaming and frying processes, accompanied by liquid waste management (Peng *et al*., 2024). Based on observations, the total expenditure on electricity, LPG, and firewood in the production process reached IDR 2,915,000 per month, with an average consumption of 1,675 watts of electricity, 98 kg of LPG, and 560 kg of firewood. Carbon emissions from the steaming process reached 84,000 kg CO_2, whereas those from the frying process amounted to 671,541 kg CO_2. Additionally, the frying process produced 128 liters of liquid waste. These calculations were based on monthly production with an average output of 1,056 kg.

To design an effective management strategy, mapping the entire flow of materials and information in the production process of *rambak* crackers is necessary. Green Value Stream Mapping (GVSM) visualizes these flows while identifying their environmental impacts (Muñoz-Villamizar *et al*., 2019; Jamil *et al*., 2020). The GVSM analyzes seven primary sources of waste: energy consumption, water usage, raw materials, waste production, transportation, emissions, and biodiversity (Jamil *et al*., 2020; Berlec *et al*., 2024).

However, the GVSM cannot be used independently to measure green productivity because it only focuses on analyzing information and material flows. Therefore, a supporting method for decision-making based on the obtained weights is required to build a green productivity measurement model. The Analytical Hierarchy Process (AHP) assists decision-making based on various predefined criteria (Verão Françozo *et al*., 2023). This method simplifies complex problems by organizing them into a hierarchy and determining the best alternative based on the evaluation of relevant criteria (Leal, 2020; Petrillo *et al*., 2023).

Based on the identified research gap, this study aims to develop an integrated green productivity measurement model for *PT Pangan Barokah Abadi* by combining the Green Productivity approach, Green Value Stream Mapping (GVSM), and AHP. The proposed model is designed to provide a quantitative assessment of both economic efficiency and environmental performance, thereby supporting strategic decision-making for operational sustainability in SMEs.

Despite the growing body of literature on green productivity and sustainable manufacturing, several limitations persist. Previous studies have primarily focused on large-scale manufacturing industries or emphasized environmental assessments without integrating economic productivity indicators into a unified measurement model (Muñoz-Villamizar *et al*., 2019; Rahko and Alola, 2024). In the context of food-processing SMEs, particularly traditional food industries, research tends to concentrate on life cycle assessment or partial environmental evaluation rather than on developing an integrated productivity measurement framework. Furthermore, GVSM is often applied as a diagnostic mapping tool without being quantitatively linked to structured decision-making models, such as the AHP.

Therefore, a research gap exists in developing an integrated green productivity measurement model that combines environmental mapping (GVSM) with multi-criteria weighting (AHP) to generate a measurable and decision-oriented Green Productivity Index (GPI) suitable for SMEs. This study addresses this gap by proposing a structured model that integrates economic and environmental performance indicators into a unified evaluation framework. The proposed approach contributes theoretically by bridging value stream environmental analysis with productivity index modeling and practically by providing a decision-support tool tailored to traditional food SMEs.

RESEARCH AND METHODS

Research Stages

This study was conducted in several systematic stages. The first stage was a preliminary study carried out through field observations and a literature review to understand green productivity concepts and identify productivity and environmental issues in the *rambak* cracker (*kerupuk rambak*) production process at PT Pangan Barokah Abadi. The second stage involved analyzing the production process, including identifying each activity, material flow, and resource use. The third stage involved conducting a mass balance analysis to determine the relationship between the input, output, and waste generated in each production stage. The fourth stage involved applying the Green Value Stream Mapping (GVSM) method to map production activities and identify environmental waste sources. The fifth stage involved determining the green productivity criteria and indicators through expert discussions. The sixth stage involved applying the Analytical Hierarchy Process (AHP) to determine the relative weights of the environmental and economic indicators. Finally, the Economic Productivity Index (EPI), Environmental Productivity Index (EnPI), and Green Productivity Index (GPI) were calculated and analyzed to evaluate the overall green productivity performance.

Data Collection

The data used in this study were obtained from both primary and secondary sources. Primary data were collected through direct observation of the *rambak* cracker production process at PT Pangan Barokah Abadi and interviews with Top Management. The observations focused on identifying the production stages, processing time, energy consumption, water usage, waste generation, and transportation activities. Secondary data were obtained from company production records and internal operational documents, including data on production volume, energy usage (electricity, LPG, and fuel), and cost information required to calculate the productivity indices.

Data Analysis

The data analysis in this study consisted of several sequential stages: (1) Analysis of the *Rambak* Cracker Production Process, (2) Mass Balance Analysis, (3) Green Value Stream Mapping (GVSM) analysis, (4) Determination of Green Productivity Criteria and Indicators, (5) AHP Weighting, (6) Productivity Index Calculation, (7) Development of the Productivity Measurement Model, and (8) Model Validation.

Analysis of the Rambak Cracker Production Process

The analysis began by identifying and describing each stage of the *rambak* cracker production process, starting from mixing, molding, steaming, drying, cutting, frying, draining, and packaging. This stage aims to understand the material flow, processing time, and resource utilization in each production activity. Process analysis provided the foundation for subsequent mass balance and environmental impact evaluations. Understanding the operational flow is essential for green productivity assessment, as it allows the identification of inefficiencies and environmental burdens across production stages (Liu *et al*., 2024; Peng *et al*., 2024).

Mass Balance Analysis

Mass balance analysis was conducted to quantify the consistency of the material flow at each production stage. The calculation follows the principle:

$$\text{Input} = \text{Output} + \text{Waste}$$

Input refers to the raw and supporting materials used in production, output refers to intermediate or final products, and waste represents material losses generated during processing (Nugraha *et al*., 2025; Rizki *et al*., 2025). This analysis enabled the identification of material losses and waste generation throughout the production process of the product.

Green Value Stream Mapping (GVSM) Analysis

The GVSM was applied to visualize the material flow, resource consumption, and environmental impacts of the production system. Production activities are classified into value-added, necessary but non-value-added, and non-value-added activities (Nugraha *et al*., 2025). Although the GVSM framework identifies seven types of environmental waste, this study focused on five types based on preliminary observations: energy consumption, water usage, solid and liquid waste, transportation, and emissions(Faulkner *et al*., 2014b).

The GVSM method allows the integration of environmental indicators into value stream analysis, thereby linking operational efficiency with sustainability performance (Faulkner and Badurdeen, 2014; Muñoz-Villamizar *et al*., 2019; Jamil *et al*., 2020; Berlec and Peperko, 2024). The environmental data collected included electricity consumption (kWh), LPG and firewood usage (kg), water consumption (kg), waste generation (kg/liter), transportation distance (km), and carbon emissions (kg CO_2). Carbon emissions were estimated based on energy usage during the steaming and frying processes.

Determination of Green Productivity Criteria and Indicators

The identification of productivity criteria and indicators was conducted through brainstorming and expert discussions to ensure alignment between the economic objectives and environmental performance. This stage ensured that both business sustainability and ecological considerations were represented in the productivity model (Liu *et al*., 2024; Hou, 2025).

Analytical Hierarchy Process (AHP)

The AHP method was used to determine the relative importance weights of the economic and environmental criteria. Pairwise comparison questionnaires were distributed to three expert respondents: the Director, Operations Manager, and Production Manager. A hierarchical structure comprising value drivers, factors, and objectives was developed. Respondents evaluated each criterion using a 1–9 scale, and consistency ratios were calculated to ensure reliability (Chen *et al*., 2025; Kee *et al*., 2025; Petrillo *et al*., 2023). The consistency of expert judgments was evaluated using the Consistency Index (CI) and Consistency Ratio (CR). A CR value below 0.10 indicates an acceptable consistency. CI and CR were calculated as follows:

$$\text{Cl} = \frac{\lambda \text{ maks-n}}{\text{n-1}} \quad \text{dan} \quad \text{CR} = \frac{\text{CI}}{\text{RI}}$$

where RI is random index.

Productivity Index Calculation

The green productivity measurement model consists of three indices: Economic Productivity Index (EPI), Environmental Productivity Index (EnPI), and Green Productivity Index (GPI).

EPI was calculated as the ratio between total revenue and total production cost:

$$\text{EPI} = \text{Total Revenue} / \text{Total Production Cost}$$

EnPI was calculated by aggregating environmental indicators weighted by AHP results:

$$\text{EnPI} = \Sigma\ (\text{Wi} \times \text{Ei})$$

where Wi represents the weight of environmental factor i, and Ei represents the environmental performance value.

GPI integrates economic and environmental performance:

$$\text{GPI} = \text{EPI} / \text{EnPI}$$

This index provides a comprehensive measure of green productivity performance.

Development of the Productivity Measurement Model

A productivity measurement model was developed by integrating the results of the GVSM analysis and AHP weighting into a structured green productivity framework. The model consists of three main components: the Economic Productivity Index (EPI), Environmental Productivity Index (EnPI), and Green Productivity Index (GPI). EPI represents the economic performance of the production system and is calculated as the ratio of total revenue to total production cost. EnPI represents the aggregated environmental performance derived from weighted environmental indicators identified through the GVSM and prioritized using the AHP. The Green Productivity Index (GPI) was formulated as the ratio of EPI to EnPI. This integrated formulation enables the simultaneous evaluation of economic efficiency and environmental impact within a unified measurement framework.

EPI represents financial performance and is calculated as the ratio of total revenue to total production cost. Profitability was selected because it integratively captures the overall operational efficiency and financial sustainability in SME contexts. EnPI represents environmental performance derived from weighted operational indicators identified through the GVSM and prioritized using the AHP. As environmental performance is inherently multidimensional, it requires decomposition into specific indicators before aggregation. The balance between the economic and environmental dimensions is achieved through their integration in the GPI, rather than through an equal number of indicators.

Model Validation

Model validation was conducted to ensure the logical consistency and practical relevance of the developed green productivity measurement model. Validation was performed through expert judgment involving the same respondents who participated in the AHP weighting. Feedback from the respondents confirmed that the model structure, weighting system, and index formulation appropriately reflected the production characteristics and environmental performance of PT Pangan Barokah Abadi. Therefore, the model is considered valid for use as a decision-support tool for evaluating green productivity performance.

RESULTS AND DISCUSSION

The production of *rambak* crackers (*kerupuk rambak*) in a single production cycle yielded 131.5 kg of finished crackers. The production process of *kerupuk rambak Jawa* (Javanese *rambak* crackers) consists of several interrelated sequential stages. The process flow diagram for producing *kerupuk rambak Jawa* is shown in Figure 1. After mapping the production process flow, a mass balance analysis was performed. Table 1 shows the results of the mass balance analysis at each stage of *kerupuk rambak* production.

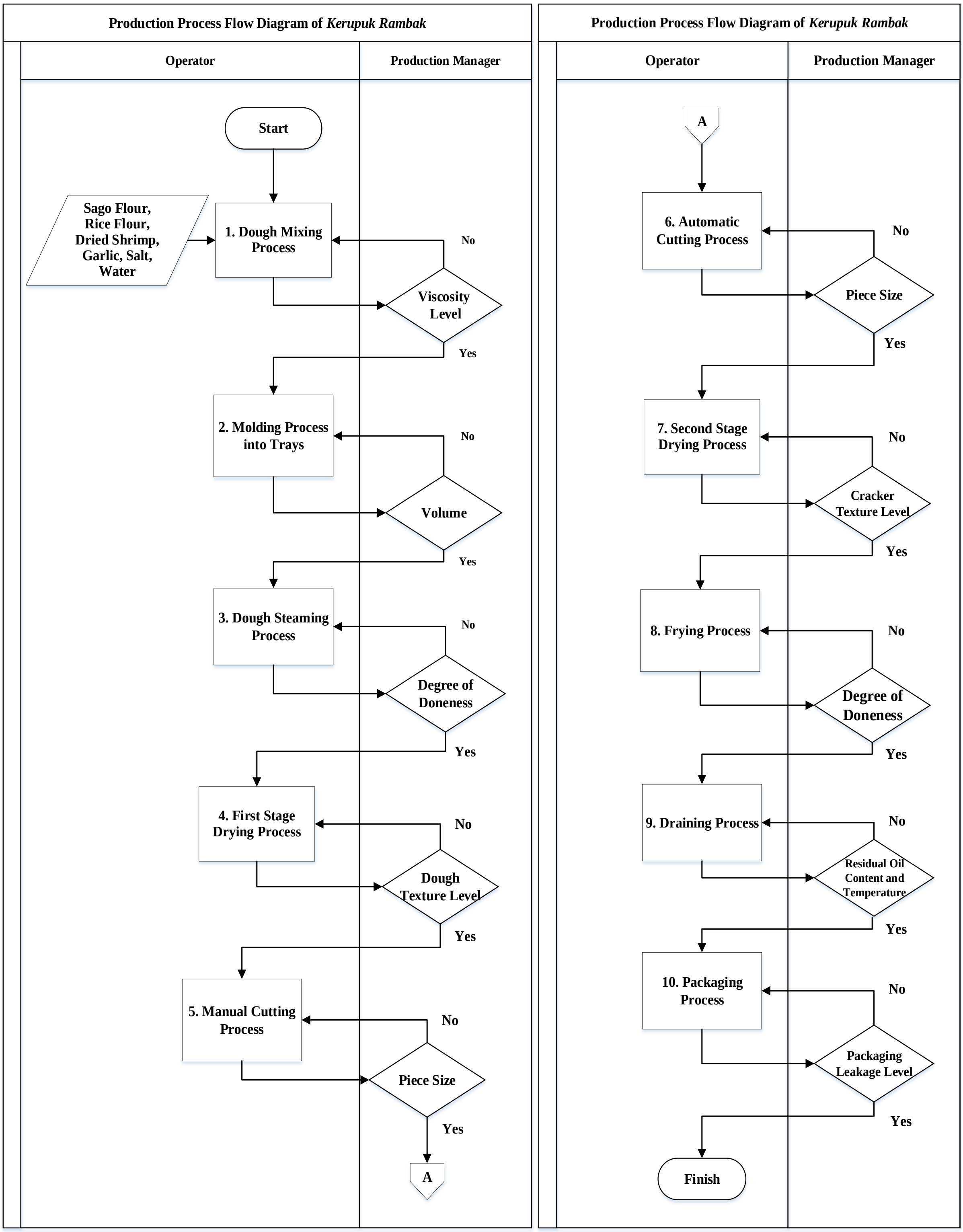

Figure 1. Flow diagram of the *rambak* cracker (*kerupuk rambak*) production process

Table 1. Results of mass balance analysis of *rambak* cracker production

No.	Process	Input	Output	Waste
1	Dough mixer	347 kg	347 kg	-
2	Molding into Baking Trays	347 kg	346 kg	1 kg (dough wastewater)
3	Steaming the Dough	346 kg	311.4 kg	-
4	First drying stage	311.4 kg	255.3 kg	-
5	Manual cutting	255.3 kg	255.3 kg	-
6	Machine cutting	255.3 kg	255.3 kg	-
7	Second drying stage	255.3 kg	163.4 kg	-
8	Frying	162.7 kg	135 kg	11.4 kg (oil waste)
9	Draining	135 kg	130.4 kg	4.6 kg (draining residue waste)
10	Packaging	132.1 kg	131.5 kg	0.6 kg (crumb waste)

Mapping was conducted using the GVSM approach to determine the extent to which production activities impact the environment and to identify sources of waste during the production process of *rambak* crackers. This mapping aims to measure the performance of the production process not only in terms of time and output but also in terms of environmental sustainability. In this study, mapping was conducted for five primary sources of environmental waste: energy, water, waste, transportation, and emissions. The results of this mapping are presented in the current state of GVSM in Figure 2.

Based on the mapping results, raw materials were sourced from suppliers located 18.5 km away, resulting in transportation emissions of 3.46 kg CO_2. The production process began with the mixing stage, which lasted for 140 min and produced an output of 347 kg. During this stage, 2.76 kWh of energy and 98 kg of water were consumed, resulting in the emission of 2.4 kg CO_2. Next, the dough is poured into molds for 105 min, with an output of 346 kg and generating an initial waste of 1 kg. The following process was steamed for 30 min, producing an output of 311.4 kg and generating the highest emissions at 117.6 kg CO_2. After steaming, the first drying stage was conducted for 240 min until the product weight decreased to 255.3 kg. The product is then cut manually for 65 min and using a machine for 35 min, with energy consumption of 0.12 kWh and additional emissions of 0.1 kg CO_2.

The second drying stage took 720 min and reduced the product weight to 163.4 kg. The frying process lasted 300 min, producing 135 kg of output, 11.4 kg of solid waste, and 18.5 kg of CO_2 emissions. After frying, the crackers were drained for 10 min until the final weight reached 127 kg, generating an additional 4.6 kg of waste. Finally, the packaging process took 240 min, consumed 2.4 kWh of energy, and generated 2.09 kg CO_2 emissions. The final product was then delivered to consumers over a distance of 10 km, producing additional transportation emissions of 1.87 kg CO_2.

Based on the total results of the GVSM mapping, the total production process time reached 1,885 min with a final product yield of 131.5 kg. The energy consumption, water usage was 98 kg, total carbon emissions, and production waste were 7.8 kWh, 98 kg, 129.1 kg CO_2, and 16 kg, respectively. The total transportation distance traveled for raw material procurement and product distribution was 28.5 km. Through this mapping, we found that the largest source of environmental impact was the steaming and frying processes, which significantly contributed to carbon emissions. Additionally, high water usage occurs during the mixing stage, and most of the solid waste is generated from the frying and draining processes.

The criteria and indicators of the green productivity measurement model were determined to ensure that all important aspects, both economic and environmental, could be comprehensively represented in the SMEs' performance evaluation process. This identification process was carried out through brainstorming and focus group discussions with experts in industrial productivity, environmental management and energy. This approach is systematically implemented to align business sustainability goals with efficient and environmentally friendly production practices.

The brainstorming process resulted in two main groups of criteria: (1) Economic Criteria, which focuses on profitability as the primary measure of financial success. (2) Environmental Criteria consist of various indicators that reflect resource efficiency and the ecological impact of production processes. Table 2 presents the results of the productivity indicator calculations based on the actual data from the cracker production process, including the production output and the amount of energy, water, and waste consumed.

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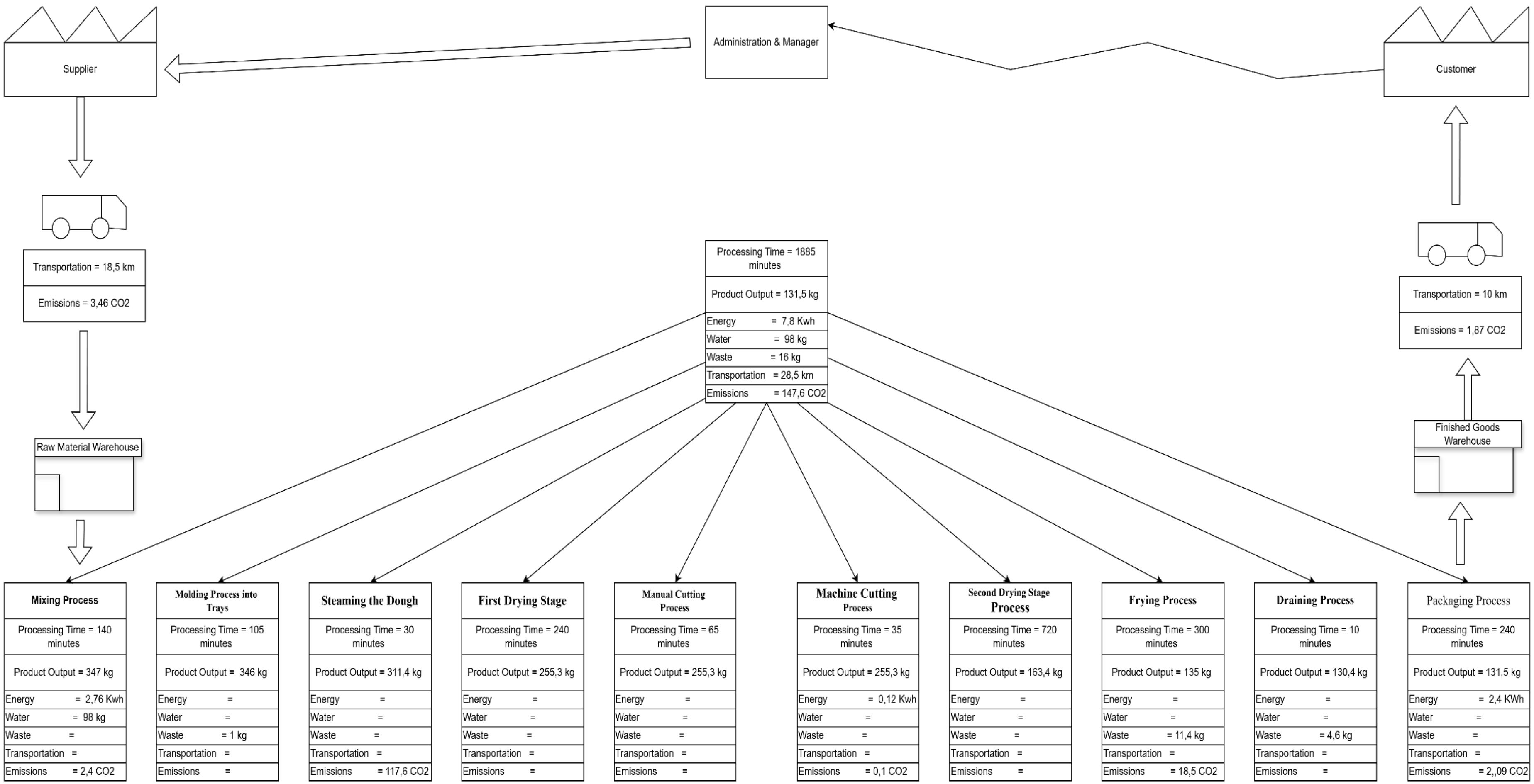

Figure 2. Green value stream mapping (current state)

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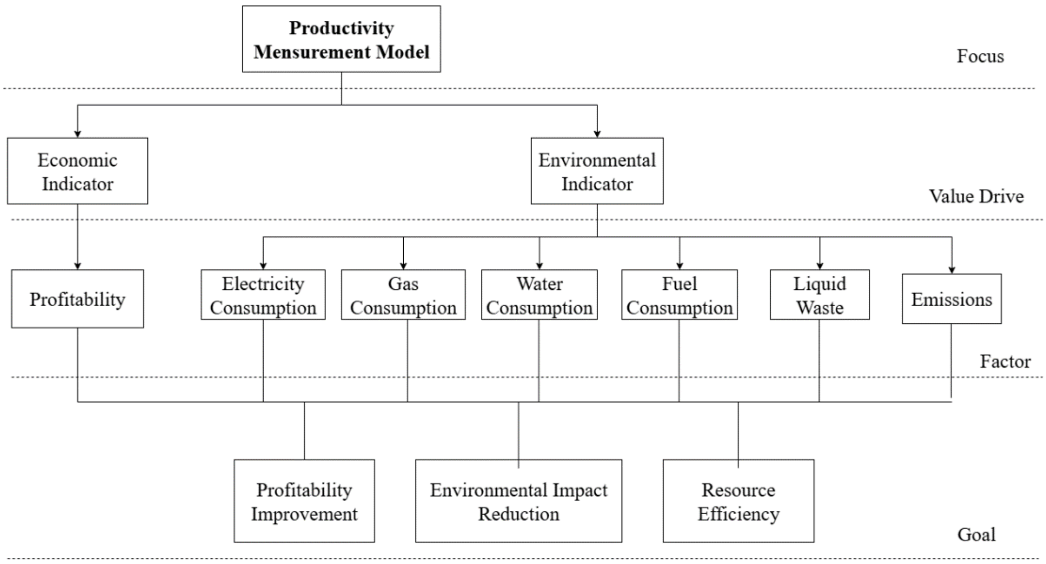

Figure 3. Hierarchical structure of the productivity measurement model

Table 2. Productivity criteria and indicators

No.	5 Waste	Criteria	Indicator		
1.	Energy	Electricity consumption	$=\frac{\text{Production Output}}{\text{Electricity Consumption}}$	$=\frac{131.5\text{ kg}}{7.8\text{ kWh}}$	16.8 kg/kWh
		Lpg gas consumption	$=\frac{\text{Production Output}}{\text{LPG Gas Consumption}}$	$=\frac{131.5\text{ kg}}{12\text{ kg}}$	10.71 kg
2.	Water	Water consumption	$=\frac{\text{Production Output}}{\text{Water Consumption}}$	$=\frac{131.5\text{ kg}}{98\text{ kg}}$	1.31 kg
3.	Waste	Liquid waste	$=\frac{\text{Production Output}}{\text{Liquid waste}}$	$=\frac{131.5\text{ kg}}{16\text{ kg}}$	8.21 kg
4.	Transportation	Fuel consumption	$=\frac{\text{Production Output}}{\text{Fuel Consumption}}$	$=\frac{131.5\text{ kg}}{2.28\text{ liter}}$	57.67 kg/liter
5	Emission	Carbon emission	$=\frac{\text{Production Output}}{\text{Carbon Emission}}$	$=\frac{131.5\text{ kg}}{147.6\text{ kg }/CO_2}$	0.89 kg/CO_2

Table 3. Priority results for value drives

No.	Factor	Weight Value	Consistency Ratio	Priority Order
1	Economic Productivity Index	0.32	0.00%	II
2	Environmental Productivity Index	0.68		I

The productivity measurement model in this study was developed using the Analytical Hierarchy Process (AHP), which involved assigning weights to each type of waste. These weights were used to calculate the Environmental Productivity Index (EnPI), followed by the Economic Productivity Index (EPI). The integration of both indices resulted in the Green Productivity Index (GPI).

The questionnaire was distributed to respondents (experts) who were considered to have sufficient knowledge and experience in their work, as well as influence on improving production processes at PT Pangan Barokah Abadi. The respondents included the Director (Respondent 1), Operations Manager (Respondent 2), and Production Manager (Respondent 3). A hierarchical structure was developed to facilitate the decision-making framework after identifying the focus, value drivers, factors and objectives. This structure, as shown in Figure 3, serves as the foundational stage in addressing productivity issues in the production process of *rambak* crackers through the application of AHP.

The next step was to calculate the weight at each hierarchy level. The weighting calculation is based on the values provided by the respondents in the questionnaire. The first questionnaire calculation was performed at the first level of the hierarchy. At this level, two main value drivers will be compared in pairs:

economic and environmental indicators. Three respondents completed the questionnaire and assigned values on a scale of 1 to 9 to each paired value driver. Based on the calculations, the priority order of the value drivers can be determined according to the priority weight values obtained, with the highest weight value occupying the first position. The results are presented in Table 3.

The next stage is the calculation of the results of the paired comparison questionnaire between factors. In the paired comparison between factors, there are two perspectives, namely (1) the results of the paired comparison questionnaire between factors in the economic indicator perspective, which has a 1×1 matrix with the profitability factor, and (2) the results of the paired comparison questionnaire between factors in the environmental indicator perspective, which has a 6×6 matrix with the factors of electricity consumption, gas consumption, water consumption, fuel consumption, liquid waste, and emissions. Based on the calculations performed, the priority order of factors can be determined based on the priority weight values obtained, with the highest weight value occupying the first position. The results can be seen in Table 4.

The next step was to calculate the results of the paired comparison questionnaire for the objectives. This calculation was performed at the third hierarchical level. At this level, objectives will be compared in pairs, namely, increased profitability, environmental impact, and resource efficiency. The questionnaire was completed by three respondents, who scored 1–9 for each paired objective. Based on the calculations performed, the priority order of the factors can be determined based on the priority weight values obtained, with the highest weight value occupying the first position. The results are presented in Table 5. The calculated consistency ratio (CR) values for all expert respondents were below 0.10 (Tables 4 and 5), indicating acceptable consistency of judgments.

After determining the relative importance weights using the AHP method, the next step was to determine the green productivity measurement model using the Economic Productivity Index, Environmental Productivity Index, and Green Productivity Index. The results for each index are presented in Table 6.

Table 6. Results of indices in the green productivity measurement model

Index	Value
Economic Productivity Index (EPI)	1.31
Environmental Productivity Index (EnPI)	35.25
Green Productivity Index (GPI)	0.037

The calculated Green Productivity Index (GPI) in the current state is 0.04. Although this value appears low, its interpretation requires a contextual benchmark. In green productivity assessment, a GPI value below 1 generally indicates that the environmental burden outweighs the economic productivity achieved, whereas a value approaching or exceeding 1 reflects a more balanced or sustainable performance of the system.

Table 4. Priority results of factors under the environmental indicator perspective

No.	Factor	Weight Value	*Consistency Ratio*	Priority Order
1	Electricity Consumption	0.23	2.20%	I
2	LPG Gas Consumption	0.23		II
3	Water Consumption	0.05		VI
4	Fuel Consumption	0.09		V
5	Liquid Waste	0.22		III
6	Emission	0.17		IV

Table 5. Priority results of the goals

No	Goal	Weight Value	*Consistency Ratio*	Priority Order
1	Profitability Improvement	0.16	0.2%	III
2	Environmental Impact Improvement	0.60		I
3	Resource Efficiency	0.24		II

Compared to previous studies in small-scale manufacturing and food processing sectors, green productivity values at the early implementation stage typically range below 0.5 because of high energy intensity and inefficient resource utilization (Muñoz-Villamizar *et al*., 2019; Liu and Yu, 2024). Therefore, the obtained value of 0.04 suggests that PT Pangan Barokah Abadi is still at an initial stage of green productivity performance, where environmental impacts, particularly emissions from steaming and frying, remain disproportionately high compared to economic returns.

From an eco-efficiency perspective, as emphasized by the Asian Productivity Organization (APO, 2019), sustainable productivity is achieved when economic value creation increases, while environmental impacts decrease. Thus, the current GPI value highlights significant opportunities for improvement, particularly in energy optimization, emission reduction, and waste minimization strategies within the production system.

This finding is consistent with the sustainability challenges commonly observed in traditional food SMEs, where production systems depend heavily on thermal energy sources such as LPG and firewood. Such reliance tends to increase carbon intensity and reduce eco-efficiency. Similar patterns have been reported in food-processing SMEs in developing economies, where environmental management practices are often implemented reactively rather than being strategically integrated into productivity measurement frameworks. This comparison strengthens the positioning of this study within the broader green productivity literature.

Future State Scenario Analysis

To enhance the practical relevance of the findings, a future-state scenario was developed based on the improvement opportunities identified through the GVSM analysis. The primary focus of the improvements was on the steaming and frying processes, which contributed most significantly to carbon emissions and energy consumption.

A simulation-based scenario was conducted, assuming a 15% reduction in LPG consumption through process heat optimization and improved thermal insulation, along with a 10% reduction in liquid waste through improved oil management practices. Under this projected condition, the Environmental Productivity Index (EnPI) decreases proportionally, resulting in an estimated improvement in the Green Productivity Index (GPI) from 0.04 to approximately 0.06–0.07 (see Table 7). Although the projected GPI remains below 1, this simulated improvement demonstrates that incremental resource efficiency strategies can significantly enhance the eco-efficiency performance of SMEs. This future-state projection strengthens the managerial implications of the model by illustrating how targeted operational interventions can improve green productivity over time.

Table 7. Projected improvement scenario

Indicator	Current State	Future Scenario	% Improvement
LPG consumption	98 kg	83.3 kg	-15%
Liquid waste	128 L	115.2 L	-10%
EnPI	35.25	~31–32	↓ (decrease)
GPI	0.037	0.06–0.07	↑ (increase)

The findings show that energy use in steaming and frying is the primary factor affecting the green productivity performance. Therefore, SME managers should prioritize improving thermal efficiency and reducing LPG and waste levels. The integration of the GVSM and AHP offers a structured decision-support tool for identifying high-impact improvement areas. The Green Productivity Index (GPI) can also function as a monitoring metric for tracking sustainability progress.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The *rambak* cracker (*kerupuk rambak*) production process at *PT Pangan Barokah Abadi* was comprehensively mapped using the current-state GVSM approach. The mapping incorporated a mass balance analysis to identify the input, output, and waste at each production stage. The results indicate that steaming and frying processes contribute most significantly to environmental impacts, particularly in terms of carbon emissions. To develop an effective model for measuring productivity, relevant criteria and indicators were systematically determined through brainstorming sessions and focused discussions with experts. These experts had experience and knowledge in industrial productivity, environmental management, and energy efficiency. The objective was to ensure that economic and environmental aspects are thoroughly represented in sustainable small and medium enterprise operations. The outcome of this process was the formulation of two main groups of criteria. Economic criteria focus on business profitability as a key indicator of financial performance.

In contrast, environmental criteria reflect the efficiency of resource use and the ecological impact of the production process. Together, these criteria form the foundation for measuring green productivity. The green productivity model developed in this study is based on calculating the Green Productivity Index, which is the ratio between the Economic Productivity Index and the Environmental Productivity Index. The Economic Productivity Index is calculated by multiplying the total number of crackers produced by the selling price per pack and then dividing that value by the total production cost. The Environmental Productivity Index was derived by assigning weights to each type of waste based on its environmental impact. These weights included 0.23 for electricity consumption, 0.23 for gas consumption, 0.05 for water consumption, 0.09 for fuel consumption, 0.22 for liquid waste, and 0.17 for emissions. This green productivity model provides a balanced and measurable approach to evaluating the sustainability performance of *PT Pangan Barokah Abadi's* production process, considering not only output and profitability but also the ecological consequences of its operations.

Recommendations

Based on the conclusions of this study, companies are advised to regularly monitor and record their energy, water, emissions, and waste consumption. These data are important as a basis for routine evaluation to assess the effectiveness of implemented resource efficiency policies. Future researchers are recommended to develop a green productivity measurement model by expanding waste indicators to include the seven main sources of waste according to the GVSM concept comprehensively, and integrating future state simulations as the basis for formulating process improvement strategies based on the highest priority weights, and formulate a future state improvement plan to minimize waste in every production activity and enhance the economic value of the product.

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