Journal of Economics AND MANAGEMENT SCIENTIES
https://jems.ink
ISSN 2655-1934 (print), 2655-6685 (online)

Exploring the Accounting for Plastic Waste Processing Costs from a Sustainability Perspective

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ARTICLE HISTORY

Received: 05 March 26
Final Revision: 23 March 26
Accepted: 08 April 26
Online Publication: 30 June 26

KEYWORDS

Sustainability Accounting, Waste Management, Pyrolysis, Plastic Waste, Cost Analysis

A B S T R A C T

This study aims to explore and analyze the cost structure of plastic waste processing through a sustainability perspective. The case study was conducted at the waste processing unit of the Central Sulawesi Provincial Environmental Agency from April to December 2025, to understand the economic efficiency behind environmental conservation efforts. Using a descriptive approach with the Activity-Based Costing (ABC) method, this study identified and allocated costs based on actual resource-consuming activities. Data were collected through field observations, interviews, and operational documentation. The results indicate that the main activities include collection, sorting, production through pyrolysis, feasibility testing, and machine maintenance. With a total processing cost of IDR 44,590,100, 283.93 liters of fuel oil were produced, resulting in a production cost of IDR 157,046 per liter. The largest burden lies in collection activities. Meanwhile, the production process is heavily dominated by energy consumption. Holistically, although current production costs are relatively high, from a sustainability perspective, this initiative proves its significance in three pillars of sustainability: the environmental aspect through reducing the waste burden, the economic aspect through creating new value, and the social aspect through empowering local communities. The results of this study imply that plastic waste management has the potential to be developed sustainably through increased operational efficiency and optimization of production scale, including the use of technology in plastic waste processing.

KATA KUNCI

Akuntansi Keberlanjutan, Pengelolaan Limbah, Pirolisis, Limbah Plastik, Analisis Biaya

A B S T R A K

Penelitian ini bertujuan untuk menelusuri dan menganalisis struktur biaya pengolahan limbah plastik melalui kacamata keberlanjutan (*sustainability*). Studi kasus dilakukan pada unit pengolahan limbah milik Dinas Lingkungan Hidup Provinsi Sulawesi Tengah selama periode April hingga Desember 2025, guna memahami efisiensi ekonomi di balik upaya pelestarian lingkungan. Melalui pendekatan deskriptif dengan metode *Activity-Based Costing* (ABC), penelitian ini mengidentifikasi dan mengalokasikan biaya berdasarkan aktivitas riil yang mengonsumsi sumber daya. Data dikumpulkan melalui observasi lapangan, wawancara, dan dokumentasi operasional. Hasil penelitian menunjukkan bahwa aktivitas utama meliputi pengumpulan, penyortiran, produksi melalui pirolisis, uji kelayakan, dan pemeliharaan mesin. Dengan total biaya pengolahan sebesar Rp44.590.100 dihasilkan 283,93 liter bahan bakar minyak. sehingga diperoleh harga pokok produksi sebesar Rp157.046 per liter. Beban terbesar terletak pada aktivitas pengumpulan. Sementara proses produksi sangat didominasi oleh konsumsi energi. Secara holistik, meskipun biaya produksi saat ini tergolong tinggi. Namun dalam perspektif keberlanjutan, inisiatif ini membuktikan signifikansinya dalam tiga pilar keberlanjutan. Yaitu, aspek lingkungan melalui pengurangan beban sampah, aspek ekonomi melalui penciptaan nilai baru, dan aspek sosial melalui pemberdayaan masyarakat lokal. Hasil penelitian ini berimplikasi bahwa pengelolaan limbah plastik berpotensi untuk dikembangkan secara berkelanjutan melalui peningkatan efisiensi operasional dan optimalisasi skala produksi, termasuk penggunaan teknologi dalam pengolahan limbah plastik.

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DOI

10.37034/jems.v8i3.420

1. Introduction

1.1. Research Background

Economic analysis is a crucial element in assessing the sustainability feasibility of plastic waste processing technologies. Many studies on pyrolysis technology discuss the efficiency and productivity of plastic conversion, but few thoroughly evaluate the cost structure involved in all phases of waste processing. This makes cost analysis in waste processing a crucial point from a sustainability perspective. A scientific report published in the journal Global Transitions emphasizes the need for a more detailed cost approach that reflects the actual resource consumption of processing activities, as common costing methods often provide inaccurate cost allocations and do not reflect the contribution of each activity to the total production cost [1]. One costing approach recommended in accounting literature for complex production systems is Activity-Based Costing (ABC), a method that identifies and allocates costs based on activities and relevant cost drivers. The application of ABC can help organizations and policymakers obtain a more transparent and accurate cost picture, thus supporting more informed decision-making in the context of investing in sustainability-oriented waste processing technologies.

The problem of plastic waste has become an increasingly complex global environmental challenge due to the increasing production and consumption of plastic in modern life. The volume of plastic waste generated globally continues to increase, but management mechanisms remain ineffective in many regions, particularly in developing countries. Studies show that the accumulation of plastic waste in the environment continues to pose a significant pressure on the quality of terrestrial and marine ecosystems, where plastic residues persist for very long periods and have the potential to cause physical and chemical disturbances to living organisms [2]. These findings indicate that the challenges of plastic waste management are not only quantitative but also related to the ability of social and technological systems to process these materials safely and effectively. Poorly managed plastic accumulation can cause long-term environmental problems, including the infiltration of microplastics into soil and water bodies, which can then enter the human food chain. This problem not only threatens environmental quality but also indicates that the linear approach of production, consumption, and disposal is no longer sufficient to meet the needs of plastic waste management in the 21st century.

The success of a plastic waste management system is greatly influenced by the technological capabilities used to process the material into reusable products. Sustainability principles emphasize the importance of treating waste as a resource, not simply as a discarded residue, through strategies that integrate environmental protection, economic efficiency, and social benefits. A bibliometric study identified an increasing trend in research on plastic waste processing technologies using a sustainable approach over the past three years, particularly in the application of thermochemical technologies and energy conversion mechanisms [2]. This demonstrates that the global scientific community is increasingly focusing on solutions that not only minimize negative environmental impacts but also create added value from waste. Management strategies based on circular economy principles, including converting waste into fuel or other products, are gaining attention because they can reduce dependence on primary resources while reducing the amount of waste ending up in landfills.

One technological approach widely discussed in plastic waste management research is pyrolysis. Pyrolysis is a thermochemical process that involves heating plastic material at high temperatures in the absence or very minimal presence of oxygen, causing the polymer chains to decompose into simpler compounds in the form of liquid products (pyrolysis oil), gas, and solid residue (char). Unlike mechanical recycling methods, which are limited by the type and quality of plastic, for example, they are only effective for relatively clean and sorted plastics. Pyrolysis can handle various types of polymers, such as polyethylene (PE), polypropylene (PP), and polystyrene (PS), even when mixed. The main product, pyrolysis oil, has a relatively high calorific value and has the potential to be used as an alternative fuel or raw material for the petrochemical industry. Pyrolysis not only serves as a solution to reduce the volume of plastic waste but also as an energy recovery approach that supports the principles of a circular economy and sustainable waste management [3].

Other research shows that using a pyrolysis reactor on plastic waste, such as Low-Density Polyethylene (LDPE), can produce an oil product that is energetically viable for use as an alternative fuel [4]. Other studies have also highlighted that temperature control and reactor configuration play a critical role in pyrolysis efficiency and the quality of the resulting oil product [5]. The pyrolysis process also produces residues in the form of solids and emissions that require further management to prevent new negative impacts on the environment or health. This complexity suggests that pyrolysis technology assessments must be conducted not only from a technical perspective but also from a cost, environmental impact, and social value perspective.

This research aims to analyze the costs of plastic waste processing using an Activity-Based Costing approach and evaluate the results from a sustainability perspective. The focus of this research is not only on the total cost but also on mapping the cost structure based on the main activities of the plastic waste processing process using pyrolysis technology, as well as the relationship between the cost structure, environmental benefits, and social impacts resulting from this processing. This research is expected to fill the gap in the scientific literature related to the lack of detailed cost analysis in pyrolysis-based plastic waste processing and provide an empirical contribution to the formulation of more effective, efficient, and sustainable waste management policies.

Based on this phenomenon, most research on pyrolysis-based plastic waste processing still focuses on technical aspects and material conversion efficiency. Detailed studies of cost structures using the Activity-Based Costing approach are still relatively limited, especially those linking cost analysis results to a sustainability perspective. The economic potential of plastic waste pyrolysis in sustainable management is still below the significant profit threshold, so that emphasis on operational efficiency, reactor capacity, and cost management is important in increasing economic feasibility from a sustainability perspective [6]. This study seeks to fill this gap by analyzing the costs of plastic waste processing using the ABC approach and examining its implications for environmental, economic, and social sustainability. This approach is expected to provide an empirical contribution to the development of more effective and sustainable plastic waste management policies and practices.

1.2. Literature Review

1.2.1. Plastic Waste and Sustainability Challenges

Plastic waste is a type of solid waste with a high level of persistence in the environment due to its polymer structure, which is difficult to degrade naturally. Increased plastic production and consumption are not always accompanied by increased public environmental awareness and adequate management systems, leading to waste accumulation in various urban areas. One of the biggest challenges to sustainable development in urban areas is low public environmental awareness. This suggests that behavioral change toward a sustainable lifestyle requires a systematic communication strategy, education, and innovation diffusion approach. These findings suggest that the plastic waste problem is not merely technical, but also related to behavioral factors and social awareness that influence the effectiveness of environmental management [7].

Beyond public awareness, the sustainability challenge of plastic waste is also related to consumption patterns. The importance of sustainable consumption as part of achieving the SDGs, especially goal 12 on Responsible Consumption and Production [8]. The study suggests that environmentally friendly product innovations, such as reusable bags, can be a practical solution to reducing the use of single-use plastics. This approach emphasizes that efforts to reduce plastic waste must be supported by changes in consumption patterns and the selection of more environmentally friendly products. Poorly managed plastic waste has the potential to fragment into microplastics, which can impact ecosystems and human health in the long term. The principle of sustainability demands a balance between environmental protection, economic efficiency, and social benefits. This demand directs plastic waste management not only toward volume reduction but also toward transforming consumption behavior and creating a more responsible economic system.

1.2.2. Pyrolysis Technology in Plastic Waste Processing

Pyrolysis is a thermochemical technology used to convert plastic waste into energy-valuable products through an oxygen-free heating process. This technology is considered relevant in plastic waste management because it can convert waste into a reusable alternative fuel. The application of pyrolysis technology is not only oriented toward the technical aspects of material conversion but also embraces a sustainability approach that encompasses environmental and social dimensions. The implementation of Green Chemistry principles through pyrolysis technology in Way Urang Village was able to increase public understanding of plastic types and processing methods by 51% after educational activities and demonstrations were carried out [9]. These results show that pyrolysis can function as a technical instrument as well as a means of increasing environmental literacy and community empowerment in managing plastic waste.

Low-Density Polyethylene (LDPE) plastic can be converted into alternative fuel oil through a heating, distillation, and condensation process for around 1 to 1.15 hours [10]. This process produces propane gas, which is then cooled to form a liquid fuel. These findings indicate that certain types of plastic have high potential for development as alternative energy sources. The simple pyrolysis technology used in this study demonstrates that plastic waste processing can be implemented locally with relatively simple equipment. The integration of plastic waste reduction, energy value generation, and increased public awareness demonstrates that pyrolysis technology has the potential to support a more sustainable waste management system, although it still requires process control and residue management to avoid new environmental impacts.

1.2.3. The Concept of Sustainability in Waste Management

Industrial waste management is a crucial aspect of maintaining environmental sustainability amidst the rapid growth of the industrial sector. Sustainability emphasizes meeting current needs without compromising the capabilities of future generations. In industrial waste management, this encourages the implementation of strategies that are environmentally friendly, socially safe, and still support economic growth. Industrial chemical waste management requires the active participation of all stakeholders [11]. This qualitative research, using secondary data from books, journals, and relevant websites, emphasizes the need for sustainable solutions that support responsible economic growth and environmental preservation. Synergy between government, industry, and the community is key to achieving holistic sustainability.

A case study of the pollution of the Citarum River in West Java demonstrates the real impact of poorly managed industrial waste [12]. A holistic approach combining technological innovation, strict regulations, and increased public awareness is a key strategy in sustainable waste management practices. Sustainability principles such as waste reduction, reuse, recycling, the application of clean technologies, and active community and government involvement promote more effective industrial waste management. Implementing these strategies not only reduces environmental impact but also supports responsible industrial growth and a cleaner environment for the future.

1.2.4. Activity Based Costing in Waste Processing Cost Analysis

Plastic waste management requires a clear understanding of the costs associated with each stage of the process to effectively implement sustainability strategies. The Activity-Based Costing (ABC) method is a relevant tool because it allocates costs based on activities and cost drivers, providing a more accurate picture of resource consumption than conventional methods. In hemodialysis services at Siloam Hospital Bali, ABC was used to map service costs in detail, revealing significant differences in total costs between re-use and single-use hemodialysis services, as well as differences in INACBGs rates per patient. This activity-based analysis helps the hospital understand the service cost structure more clearly and design strategies to improve efficiency and profitability [13].

Cost calculations were based on cost pool identification, practical capacity, estimated time for each activity, and capacity utilization rates. The analysis revealed inefficiencies in several cost pools, such as accommodation and cleaning costs, while also uncovering idle capacity that could be optimized to improve efficiency and service quality [14]. The application of ABC to plastic waste processing allows for cost mapping of each activity, from collection and sorting to production and machine maintenance. With detailed cost information, management can assess the most resource-intensive activities and identify areas for improvement, making waste management more efficient, cost-effective, and sustainable. This approach also supports realistic economic planning and long-term resource optimization.

2. Research Methods

This study uses a descriptive qualitative approach to analyze the costs of plastic waste processing based on pyrolysis technology and review it from a sustainability perspective. The descriptive approach is used to systematically describe all plastic waste processing activities, from collection and sorting to the production process and management of residual products. Descriptive research aims to describe phenomena systematically, factually, and accurately regarding the facts and characteristics of the object being studied [15]. A quantitative approach is used to process numerical data in the form of operational costs and production output to obtain an accurate picture of the cost structure.

The main focus of this study is the application of the Activity Based Costing (ABC) method as a cost analysis tool, because this method is able to allocate costs based on relevant activities and cost drivers. Activity Based Costing (ABC) is a costing method that allocates costs based on activities and resource consumption more accurately than traditional methods [16]. The study was conducted at the Environmental Service of Central Sulawesi Province in a plastic waste processing unit that uses a pyrolysis machine. The research period covered plastic waste processing activities from April 22 to December 31, 2025, so the analyzed data reflects actual operational conditions over a relatively long production period [17].

The secondary data used in this study were obtained through a documentation study method. Documentation study is a data collection technique carried out by utilizing various written documents that are available and have relevance to the research object. [17]. Data were collected from operational reports, activity records, and official documents related to plastic waste processing. This data includes the amount of plastic waste collected and sorted, the type and weight of plastic waste, collection costs, sorting costs, electricity and gas consumption in the pyrolysis process, machine maintenance costs, production feasibility testing costs, and data on primary outputs and by-products. The documentation study technique was chosen because the required data is systematically available and well-documented, thus providing accurate and accountable information. The collected data was then grouped based on the primary plastic waste processing activity to facilitate the cost analysis process using an activity-based approach.

Data analysis was conducted using the Activity Based Costing (ABC) method through several stages, namely identifying the main activities of plastic waste processing, determining cost drivers for each activity, calculating cost rates based on resource consumption, and allocating costs to the main output in the form of pyrolysis fuel oil. The activities analyzed included collection, sorting, production, feasibility testing, and machine maintenance. The results of the Activity Based Costing (ABC) method calculations were used to determine the total production cost and the cost of production per liter of fuel. Next, the results of the waste processing cost analysis were examined from a sustainability perspective by reviewing three main aspects: the environmental aspect through reducing the volume of plastic waste, the economic aspect through cost efficiency and product added value, and the social aspect through workforce involvement and utilization of production results for the community. This approach was used to assess the feasibility of pyrolysis-based plastic waste processing in a comprehensive and sustainable manner.

3. Results and Discussion

3.1. Identification of Plastic Waste Processing Activities

The research results show that pyrolysis-based plastic waste processing comprises several key interrelated activities, forming a coherent chain of processes. These activities begin with plastic waste collection, followed by sorting, pyrolysis production, product feasibility testing, and machine maintenance. These activities were identified based on the operational flow implemented by the Central Sulawesi Provincial Environmental Agency during the research period. Each activity has a distinct purpose and function, but all contribute to the successful processing of plastic waste into useful products.

The collection activity serves as the primary source of raw material, in the form of plastic waste from the community. This stage determines the quantity and continuity of the plastic waste supply to be processed. The sorting activity separates plastics suitable for pyrolysis processing from those unsuitable for processing, thus playing a crucial role in maintaining the quality of the raw materials. The pyrolysis production process is the core activity that converts plastic waste into fuel oil. This activity involves the use of electricity and LPG as a heat source. Furthermore, feasibility testing is conducted to ensure the quality of the product, while regular machine maintenance is carried out to maintain the performance and sustainability of the pyrolysis machine.

The results of activity identification show that each activity consumes different resources, including labor, energy, and supporting materials. These differences in resource consumption led to different cost structures for each activity. Activity mapping is an important initial step in implementing the Activity Based Costing (ABC) method. Detailed activity identification allows for more accurate allocation of plastic waste processing costs based on the activities that actually consume resources during the processing process.

Table 1. Identification of Plastic Waste Processing Activities

No	Activity	Activity Description
1	Collection	Collecting plastic waste from the community
2	Sorting	Separating plastic suitable for pyrolysis
3	Production (Pyrolysis)	Converting plastic waste into fuel oil
4	Feasibility Testing	Testing the quality of production results
5	Machine Maintenance	Maintenance and cleaning of pyrolysis machines

Based on Table 1, it can be seen that the plastic waste processing process focuses not only on production activities but also involves supporting activities that play a crucial role in maintaining the quality and sustainability of the process. Collection and sorting activities are at the initial stage and serve as raw material quality control, while feasibility testing and machine maintenance activities control the quality of the output and equipment reliability. The presence of all these activities demonstrates that plastic waste processing is a complex process that requires structured management.

The results of this activity identification form the basis for determining cost drivers and calculating costs in subsequent analysis stages. By identifying the activities involved in the plastic waste processing process, this study can allocate costs more accurately and generate accurate cost information. The data in this subchapter is then used to compile an activity-based cost analysis and calculate the cost of production for pyrolysis fuel oil.

3.2. Plastic Waste Collection and Sorting

The research results indicate that plastic waste collection is the initial stage that determines the availability of raw materials for the pyrolysis-based plastic waste processing process. Collection is carried out through barter mechanisms and environmental activities involving community participation. During the research period, 110 sacks of plastic waste were collected, with an average capacity of 8–10 kg per sack. This activity took place in stages, following environmental activities organized by the Central Sulawesi Provincial Environmental Agency. Operationally, plastic waste collection requires resources in the form of labor, supporting facilities, and relatively high operational costs compared to other activities.

After the plastic waste is collected, a sorting process is carried out to separate plastic that is suitable for processing using pyrolysis technology. The sorting results indicate that not all incoming plastic waste can be further processed. During the research period, a total of 1,083.6 kg of incoming plastic waste was recorded. Of this total, 700.9 kg of plastic waste met the criteria for further processing. Unsuitable plastics, such as polyethylene terephthalate (PET) and polyvinyl chloride (PVC), are separated because they can damage machinery and reduce production quality. The sorting process is manual and requires high precision to ensure that the raw materials entering the production process meet the required specifications.

The sorting activity also has cost consequences, depending on the amount of plastic waste handled. The sorting fee is set at IDR 1,000 per kilogram of plastic waste processed. Based on the amount of plastic waste received, the total sorting cost during the study period reached IDR 1,083,600. This cost reflects the labor and time required to separate the plastic waste by type. The results of this collection and sorting process demonstrate that the initial stages of plastic waste processing serve not only as a raw material provider but also as a quality control measure before the plastic waste enters the production stage.

Table 2. Results of Plastic Waste Collection and Sorting

Description	Quantity
Total incoming plastic waste	1,083.6 kg
Sorted plastic waste	700.9 kg
Unsuitable waste	382.7 kg
Sorting fee	IDR 1,083,600

Table 2 shows a significant difference between the amount of plastic waste received and that which can be processed through pyrolysis. This difference indicates that the sorting process plays a crucial role in maintaining the quality of the raw materials and preventing the risk of damage to the pyrolysis machine. Unsuitable plastic waste is separated early on to prevent disruption to the production process and the resulting output quality.

The results of this plastic waste collection and sorting process serve as the basis for determining the amount of plastic waste that can be processed during the production phase. This data is then used in the pyrolysis process analysis and production cost calculations using the Activity-Based Costing method. Therefore, the collection and sorting stages are directly related to the effectiveness of the production process and the overall cost structure of plastic waste processing.

3.3. Pyrolysis Production Process

The results of the study indicate that the pyrolysis production process is a key step in processing plastic waste into fuel oil. This process involves feeding sorted plastic waste into a pyrolysis machine with a capacity of 20 kg per process. During the study period, the amount of plastic waste successfully processed through pyrolysis reached 501.1 kg. The production process is carried out in stages depending on raw material availability and machine readiness. This activity requires stable temperature control and a specific operating time to ensure optimal conversion of plastic waste into fuel oil.

The pyrolysis process uses electricity and LPG as energy sources. Electricity consumption was recorded at 300 watts per hour for each production process, while LPG usage reached 5 kg per process. Based on operational data during the research period, the total electricity cost for the pyrolysis process reached IDR 340,500 per year. Meanwhile, the cost of LPG gas was recorded at IDR 3,876,000 per year. Energy consumption is a significant component of the production cost structure because it is directly related to the intensity of the heating process required in the pyrolysis technology.

The results from the pyrolysis process indicate that the processed plastic waste can be converted into fuel oil as the primary product. This process also produces by-products, which will be discussed in the next subchapter. These results demonstrate that the pyrolysis technology is capable of processing plastic waste consistently throughout the research period. The production data obtained is the basis for calculating production costs and production costs using the Activity Based Costing (ABC) method.

Table 3. Results of the Production Process Through Pyrolysis

Description	Quantity
Processed plastic	501.1 kg
Electricity consumption	300 watts/hour
Electricity costs	Rp. 340,500
LPG gas consumption	5 kg/process
LPG gas costs	IDR 3,876,000

Based on Table 3, it can be seen that the pyrolysis production process requires significant energy consumption, particularly for the use of LPG gas. This energy cost is a major component of the total cost of plastic waste processing. The high energy requirement indicates that the efficiency of the pyrolysis process is significantly influenced by the management of energy used during production.

The results of this pyrolysis production process are then used to calculate the total fuel oil output and determine the production cost per liter. This data also serves as the basis for evaluating the technical performance of the pyrolysis process in converting plastic waste into alternative energi. This production stage plays a strategic role because it directly determines the output quantity and the overall cost structure of plastic waste processing.

3.4. Production and Utilization of Residual Products

The results of the study indicate that the pyrolysis process not only produces the primary product, fuel oil, but also produces residual products with the potential for reuse. During the study period, the primary products obtained consisted of two types of fuel: diesel and gasoline. These products are produced by the condensation of steam generated by heating plastic waste at high temperatures in a pyrolysis machine. The presence of these primary products demonstrates that plastic waste can be converted into an alternative energy source that can be utilized for specific needs.

In addition to the main products, the pyrolysis process also produces byproducts in the form of black carbon and residual water. Black carbon is formed as a solid residue resulting from the incomplete combustion of plastic waste, while residual water is produced by the cooling process of steam during condensation. During the research period, the amount of black carbon produced reached 55.6 kg, while the residual water produced reached 69.1 liters. These residual products were collected and recorded as part of the production process output, allowing for comprehensive documentation of all pyrolysis results.

The production results and residual products indicate that the pyrolysis process produces diverse outputs with distinct characteristics. The main product, fuel oil, is the primary focus in calculating production costs and costs, while residual products are recorded as potential for further use. Complete data collection on all these outputs is essential to provide a complete picture of the pyrolysis process results during the research period.

Table 4. Production Results and Residual Products of the Pyrolysis Process

Output Type	Quantity
Diesel	280.8 liters
Gasoline	3.13 liters
Black carbon	55.6 kg
Residual water	69.1 liters

Based on Table 4, it can be seen that the majority of the pyrolysis process output is diesel fuel, while gasoline is produced in relatively small quantities. The presence of black carbon and residual water indicates that the pyrolysis process does not entirely produce liquid products, but also leaves solid and liquid residues. This data provides an overview of the proportion of output generated during the plastic waste processing process.

These production results and residual products are then used as the basis for further analysis regarding output utilization and the efficiency of the pyrolysis process. Information on the quantity and type of products produced is important in assessing production performance and serves as a consideration in the sustainability analysis at the discussion stage. This data also supports the calculation of the added value generated from pyrolysis-based plastic waste processing.

3.5. Cost Analysis Based on Activity-Based Costing

The results of the study indicate that the application of the Activity-Based Costing (ABC) method is able to identify and allocate plastic waste processing costs in more detail based on resource-consuming activities. The cost analysis was conducted by grouping all operational costs into primary activities: collection, sorting, pyrolysis production processes, product feasibility testing, and machine maintenance. Each activity was analyzed based on resource usage data during the study period to obtain a picture of the actual cost structure. This approach provides more representative cost information than conventional methods that focus solely on total production costs.

The calculations show that plastic waste collection is the largest cost contributor to the overall processing process. Collection costs reach IDR 32,750,000 per year, reflecting the resource requirements in the initial stages of plastic waste processing. Pyrolysis production activities also incur significant costs, primarily from the use of LPG and electricity as the primary energy sources. Feasibility testing activities contribute significantly to costs because they are carried out to ensure the quality of the fuel oil produced. Sorting and machine maintenance activities contribute relatively smaller costs, but are still necessary to support the smooth running of the processing process.

The results of this activity-based cost analysis show variations in cost contributions between plastic waste processing activities. These differences reflect the varying levels of resource consumption in each activity. By using the Activity-Based Costing method, all costs can be allocated proportionally according to the activities performed, resulting in more accurate and transparent cost information. This information serves as the basis for calculating the total production costs and the cost of production of the pyrolysis fuel oil.

Table 5. Cost Analysis Results Based on Activity Based Costing

Activities	Cost (Rp)
Collection	32,750,000
Sorting	1,083,600
Electricity	340,500
LPG Gas	3,876,000
Feasibility Testing	6,000,000
Machine Maintenance	540,000
Total	44,590,100

Table 5 shows that collection costs account for the largest portion of costs compared to other activities. This indicates that the initial stages of plastic waste processing require significant resources to ensure the availability of raw materials. Production and feasibility testing activities also contribute significantly to costs because they are directly related to the conversion process and the quality of the resulting product.

The results of this cost analysis using the Activity-Based Costing method were then used to calculate the production cost of the pyrolysis-derived fuel oil. The resulting cost data served as the basis for the total cost recapitulation and output analysis in the following sub-chapter. This sub-chapter provides a quantitative overview of the overall cost structure of plastic waste processing.

3.6. Recapitulation of Production Costs and Output

The results of the study indicate that all pyrolysis-based plastic waste processing activities generate total costs and production output that can be summarized comprehensively. This recapitulation was conducted by combining the results of the activity-based cost analysis with data on fuel oil output produced during the study period. The total cost of plastic waste processing, as calculated using the Activity-Based Costing method, reached IDR 44,590,100. This cost reflects all expenses incurred during the processing process, from the collection stage to machine maintenance.

In terms of output, the main product, fuel oil, produced from the pyrolysis process, consisted of diesel and gasoline, with a total volume of 283.93 liters. This output was obtained from processing plastic waste that had gone through the collection, sorting, and production stages. This output summary demonstrates that the pyrolysis process is capable of producing a tangible alternative energy product from previously valueless plastic waste. This output data serves as a quantitative indicator of the success of the pyrolysis-based plastic waste processing process during the research period.

Based on the total costs and total output produced, the cost of production of fuel oil was calculated. The cost of production was obtained by dividing the total processing costs by the total volume of fuel oil produced. The calculation results in a cost of production of pyrolysis fuel oil of IDR 157,046 per liter. This value reflects the actual cost incurred to produce one liter of fuel oil from processed plastic waste.

Table 6. Summary of Production Costs and Output

Description	Value
Total production costs	Rp. 44,590,100
Total fuel output	283.93 liters
Cost of production	IDR 157,046/liter

Table 6 demonstrates a direct relationship between total processing costs and the amount of fuel oil produced. This summary provides a quantitative overview of the cost performance and production output of pyrolysis-based plastic waste processing. This data serves as a reference for assessing the economic effectiveness of plastic waste processing.

The results of this summary of costs and production output then form the basis for the analysis in the discussion section. The information obtained from this sub-chapter is used to examine the implications of plastic waste processing for environmental, economic, and social sustainability. This summary concludes the research series and connects the empirical findings with the conceptual analysis in the next stage.

3.7. Discussion

The results show that plastic waste processing using pyrolysis technology makes a significant contribution to reducing the volume of plastic waste that has the potential to pollute the environment. Plastic waste that previously ended up in landfills and aquatic environments is diverted into raw materials for alternative energy production. The sorting process before the pyrolysis stage ensures that only plastic with specific characteristics enters the system, thereby reducing the risk of generating harmful emissions. These findings align with previous research, which found that operational innovation in the plastic waste processing industry, through the application of smart technology and lean manufacturing, can improve process efficiency while strengthening the sector's environmental sustainability. The study emphasized that operational innovation not only impacts cost efficiency but also the effectiveness of systematic plastic waste reduction [18]. This study emphasized that operational innovation not only impacts cost efficiency but also the effectiveness of systematically reducing plastic waste.

The results of this study also align with previous studies that found value added across each plastic waste processing supply chain, although the overall value added remained negative. This indicates that the waste-to-energy process does generate economic value, but supply chain efficiency is crucial for its sustainability [19]. This reinforces the research finding that the effectiveness of pyrolysis is determined not only by the conversion technology but also by the management of collection, distribution, and integration between actors in the waste management system. The existence of by-products such as black carbon that are reused also supports the principle of a circular economy, as explained in previous research which emphasized the importance of the full costing method so that all production costs, both fixed and variable, are taken into account in their entirety in determining the cost of production [20].

From an economic perspective, this study shows that the production cost of IDR 157,046 per liter is still relatively high compared to conventional fuels. This finding suggests that production scale and operational efficiency are determining factors for competitiveness. Previous research found that operational costs reached IDR 340,000 per ton with a minimum acceptance limit of 70% to achieve a profit of 4%, and a maximum ROI of 66.48% in the optimal scenario [21]. These results confirm that technology-based waste processing requires careful investment planning and sufficient service volume to be financially viable. This comparison suggests that pyrolysis has the potential to be a profitable business if production capacity is increased and cost structures can be reduced. Other studies identify prevention costs, internal failure costs, and environmental detection costs as important components of environmental accounting [22]. These findings are relevant to the Activity-Based Costing approach used in this study, as accurate cost allocation is key to determining the economic feasibility of pyrolysis-based plastic waste processing.

From a social perspective, research on pyrolysis-based plastic waste processing demonstrates community involvement in the collection and sorting of plastic waste prior to the pyrolysis process. This finding is supported by previous research showing that a community-based waste management model can provide real economic benefits while reducing the impact of pollution on fishermen affected by waste [23]. Previous research also confirmed that waste management accompanied by environmental accounting records can specifically prevent internal and external failures in institutional waste management. This suggests that transparency and reporting of environmental costs are essential for social and institutional sustainability [24]. Previous research has shown that plastic waste can be utilized in innovative construction materials, such as red bricks made with a mixture of plastic and sawdust, which can increase compressive strength and maintain water absorption below 20%. This finding expands the use of plastic waste and its residues, including the potential for pyrolysis derivatives in the construction sector [25].

Synthesis of various previous studies indicates similar findings regarding the role of pyrolysis technology in plastic waste management. These studies confirm that this approach makes significant contributions in environmental, economic, and social dimensions. Waste-to-energy conversion demonstrates a reduction in waste accumulation while simultaneously generating added value within the management chain. Cost analyses show that economic feasibility is strongly influenced by production scale and operational efficiency, while community involvement in waste collection is a crucial factor in maintaining a sustainable raw material supply. Key challenges lie in optimizing collection systems, increasing production capacity, and implementing accurate cost recording. Consistent support for technical innovation and policies will determine the long-term sustainability of pyrolysis technology.

4. Conclusion

Based on the research results and discussion, plastic waste processing based on pyrolysis technology is able to convert plastic waste into fuel oil and produce residual products that can still be used. The processing process includes collection, sorting, pyrolysis production, feasibility testing, and machine maintenance, which indicates that plastic waste management requires structured activity arrangements. Cost analysis using the Activity Based Costing (ABC) method shows a total processing cost of IDR 44,590,100 with a total fuel oil output of 283.93 liters, resulting in a production cost of IDR 157,046 per liter. This value indicates that production costs are still relatively high compared to conventional fuel prices, but the ABC method provides a more accurate and transparent picture of the cost structure and helps identify activities with the largest cost absorption. Pyrolysis-based plastic waste processing also makes a positive contribution to environmental aspects by reducing the volume of plastic waste and utilizing residual products. The economic aspect is seen from the creation of added value from plastic waste, while the social aspect is reflected in community involvement in waste collection activities and distribution of production results. The development of pyrolysis-based plastic waste processing still requires increased production efficiency, optimization of waste collection systems, and further studies on a larger scale to assess the economic potential and sustainability of plastic waste management more comprehensive.

Reference

[1] Dirmala, A. (2025). Tinjauan Optimalisasi Metode Pirolisis Limbah Plastik dalam Upaya Pengelolaan Limbah Rumah Tangga. *Seminar Nasional Sains Dan Teknologi (SAINTEK)*, *4*(1), 803–812.

[2] Rinanda, R., Sun, Y., Chang, K., Sulastri, R., Cui, X., Cheng, Z., Yan, B., & Chen, G. (2023). Plastic Waste Management: A Bibliometric Analysis (1992–2022). *Sustainability (Switzerland)*, *15*(24), 1. https://doi.org/10.3390/su152416840

[3] Roychand, R., Zafar, M. A., Jacob, M., & Ngo, T. (2025). A Comprehensive Review on the Thermochemical Treatment of Plastic Waste to Produce High Value Products for Different Applications. *Materials Circular Economy*, *7*(1), 1–33. https://doi.org/10.1007/s42824-024-00157-2

[4] Fatimura, M. (2020). Evaluasi Kinerja Reaktor Pirolisis Non Katalis Dalam Mengkonversikan Limbah Plastik Menjadi Bahan Bakar Minyak. *Jurnal Ilmiah Teknik Kimia*, *4*(1), 1–7. https://doi.org/10.32493/jitk.v4i1.3725

[5] Azis, H. A., & Rante, H. B. (2021). Produksi Bahan Bakar Cair Dari Limbah Plastik Polypropylene (PP) Metode Pirolisis. *Journal of Chemical Process Engineering*, *6*(1), 18–23. https://doi.org/10.33536/jcpe.v6i1.823

[6] Sari, M. M., Septiariva, I. Y., Rofiah, R., Suryawan, I. W. K., & Suhardono, S. (2024). Potensi Ekonomi Pirolisis Sampah Plastik untuk Pengelolaan Berkelanjutan: Studi Kasus Plastik Pembungkus Paket. *Jurnal Ilmu Lingkungan*, *22*(4), 941–950. https://doi.org/10.14710/jil.22.4.941-950

[7] Kurniawan, H., Umamah, R., Zuhrah, N., & Mahdalena, V. (2024). Tantangan Terbesar dalam Pembangunan Berkelanjutan. *Translitera : Jurnal Kajian Komunikasi Dan Studi Media*, *13*(2), 29–37. https://doi.org/10.35457/translitera.v13i2.3677

[8] Amin, Moch. A. M., Febriansyah, M. A., Putra, M. N., Renaldy, Ach. F., & Radianto, D. O. (2023). EverBloomBags: Menghadapi Tantangan Lingkungan dengan Gaya, Inovasi, dan Kesadaran Berkelanjutan. *VISA: Journal of Visions and Ideas*, *3*(3), 497–504. https://doi.org/10.47467/visa.v3i3.4030

[9] Sembiring, Z., Nurhasanah, N., Rinawati, R., & Simanjuntak, W. (2022). Implementasi Green Chemistry Menggunakan Teknologi Pirolisis Untuk Pengolahan Limbah Plastik Di Kelurahan Way Urang Kalianda. *Jurnal Pengabdian Kepada Masyarakat (JPKM) TABIKPUN*, *3*(1), 77–86. https://doi.org/10.23960/jpkmt.v3i1.67

[10] Bratha, R. W. K., & Putri, N. R. (2023). Inovasi Teknologi Pirolisis Sederhana Pengolah Sampah Plastik Menjadi Bahan Bakar Minyak (KEROSENE). *Jurnal Studi Inovasi*, *3*(2), 1–6. https://doi.org/10.52000/jsi.v3i2.132

[11] Putri, H. H., & Syafira, F. T. S. (2024). Pengelolaan Limbah Industri Kimia untuk Keberlanjutan Lingkungan di Indonesia. *Jurnal Ilmiah Wahana Pendidikan*, *10*(12), 290–295. https://doi.org/10.5281/zenodo.12522776

[12] Haifa, A. H., Oktaviana, A. Y., & Kamal, U. (2024). Tantangan dan Solusi Pengelolaan Limbah Industri: Upaya Menuju Lingkungan. *Jurnal Ilmiah Wahana Pendidikan*, *10*(23), 1133–1139.

[13] Margina, R. A., & Prena, G. Das. (2024). Analisis Unit Cost Layanan Hemodialisis dengan Pendekatan Activity-Based Costing sebagai Strategi Peningkatan Laba Rumah Sakit. *Al Qalam: Jurnal Ilmiah Keagamaan Dan Kemasyarakatan*, *18*(4), 2548–2560. https://doi.org/10.35931/aq.v18i4.3617

[14] Desitama, F. S., & Habib, M. A. F. (2023). Health Service Efficiency: Cost Analysis Of Time Driven Activity Based Costing Methods In Caesar Surgery Services In Pku Muhammadiyah Hospital, Yogyakarta. *Balance: Journal Of Islamic Accounting*, *4*(1), 66–87. https://doi.org/10.21274/balance_vol4no1_66-87

[15] Sugiyono. (2019). *Metode penelitian kuantitatif kualitatif dan R dan D*. Alfabeta.

[16] Hansen, D. R., & Mowen, M. M. (2007). *Managerial accounting* (8th ed.). South-Western.

[17] Arikunto, S. (2014). *Prosedur Penelitian : Suatu Pendekatan Praktik / Suharsimi Arikunto* (15th ed.). Rineka Cipta.

[18] Marlina, M., Sufitrayati, S., Amri, S., Syamsuddin, N., Radhiana, R., & Akbar, R. M. (2025). Inovasi operasional untuk efisiensi biaya dan peningkatan profit di industri pengolahan limbah plastik. *Jurnal Serambi Engineering*, *10*(1), 12562–12570.

[19] Kurniawan, B., Bahauddin, A., Trenggonowati, D. L., Dewantari, N. M., Mariawati, A. S., Sonda, A., & Wulandari, A. (2022). Analisis rantai nilai pada industri pengolahan sampah terpadu berbasis ekonomi sirkular. *Journal of Systems Engineering and Management*, *02*(01), 40–44. https://dx.doi.org/10.62870/joseam.v2i1.19239

[20] Septin, A. K., Muzakki, K., & Putrihadiningrum, D. C. (2022). Analisis Penentuan Harga Pokok Produksi Recycle Pet Flakes Dengan Metode Full Costing (Studi Kasus PT Abadi Sinar Baru Indah). *Greenomika*, *4*(1), 23–30. https://doi.org/10.55732/unu.gnk.2022.04.1.3

[21] Utami, A. A., Zahrudin, Z., Umam, K., & Susanto, R. (2022). Analisis Biaya Layanan Pengolahan Sampah Dengan Insinerator Di Tpst Mustika Ikhlas. *Journal of Applied Business and Economic (JABE)*, *9*(1), 81–91. http://doi.org/10.30998/jabe.v9i1.15953

[22] Nuwa, Y. C. A. G., Dethan, M. A., & Oematan, H. M. (2023). Analisis Penerapan Akuntansi Lingkungan Atas Pengelolaan Limbah Pada Dinas Kesehatan Kota Kupang. *Jurnal Akuntansi: Transparansi Dan Akuntabilitas*, *11*(1), 9–21. https://doi.org/10.35508/jak.v11i1.10074

[23] Ramanda, S., & Dewiyani, L. (2022). Business Plan Pemanfaatan Sampah Plastik Menjadi Bahan Bakar Minyak Sebagai Implementasi Social Entrepreneurship di Pulau Harapan. *JISI: Jurnal Integrasi Sistem Industri*, *9*(1), 13–23. https://doi.org/10.24853/jisi.9.1.13-23

[24] Hasanah, N., Sujaya, F. A., & Puspitasari, M. (2025). Analisis Penerapan Akuntansi Lingkungan terhadap Biaya Operasional Pengolahan Limbah. *Gorontalo Accounting Journal*, *8*(2), 453–459. https://doi.org/10.32662/gaj.v8i2.3735

[25] Firnas, N. D., Mahardhika, G., Hartono, H., & Fauziyah, S. (2025). Pengaruh Limbah Serbuk Kayu sebagai Pengganti Sekam Padi dan Bahan Tambah Limbah Polypropylene terhadap Kualitas Batu Bata Merah. *Jurnal Sipil Dan Arsitektur*, *3*(3), 205–210. https://doi.org/10.14710/pilars.3.3.2025.205-210

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