

# Circular Economy for Sustainable Management of Plastic Waste to Produce Liquid Fuel and the Environmental Impact of the Whole Life Cycle (Case Study in Banjarnegara, Central Java, Indonesia)

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**Abstract:** A circular economy approach that optimises materials and resources needs to be promoted to rural communities, especially in watersheds to the coast. Community-based plastic waste cleanup activities in rural areas can help reduce the vulnerability of plastic waste entering rivers to the sea. This study uses break-even point analysis to determine the break-even value in the Production of Fuel Oil from Plastic Waste at the Banjarnegara Waste Bank (BSB), also in terms of the environmental impact of the whole life cycle of a product produced by the business using a Life Cycle Assessment (LCA). BSB is an industry in Banjarnegara Regency, Indonesia, which specializes in the pyrolysis of fuel oil derived from plastic waste. BSB has never calculated the economic value of producing Fuel Oil from Plastic Waste. BSB relies exclusively on production based on social activities driven by environmental management, so the profits cannot be calculated. BSB management's income fluctuates because the break-even point for producing fuel oil from plastic waste is still being determined. The findings indicated that the annual cost for refining Fuel Oil from Plastic Waste in BSB amounted to Rp. 248,265,025 rupiah. Although the most significant contribution of environmental impact is terrestrial Acidification, followed by ocean eutrophication, stratospheric ozone depletion, water consumption, and ionising radiation, BSB's generation 5 pyrolysis innovation can suppress the adverse effects of the pyrolysis process, which involves high heat and pressure, the presence of waste, and water use.

**Keywords:** sustainability; community; energy; self-sufficiency.

## 1. Introduction

Many experts argue that activities that move towards circularity should be initiated using an economic approach that maximises the use of materials and resources. Other strategies, such as large-scale recycling, are based on sustainable production practices. This method is organised in a way that ensures environmentally conscious communities carry out massive cleanup efforts [1, 2, 3].

The underprivileged are frequently the most susceptible to climate change. Improved version: There are several contributing factors to waste in our oceans. As urban centers grow, the amount of garbage produced increases in the absence of effective waste management systems [4]. Inadequate plastic management poses increasing risks to land and sea wildlife, global environmental health, and human livelihoods. These dangers are well-documented within ecological systems, highlighting the long-term threats posed by persistent plastic pollution to wildlife worldwide [5]. Developed countries also often export their waste to developing nations and must be equipped to manage it properly. Inadequate waste management methods, such as incineration or burial of refuse, are likewise associated with a requirement for increased educational efforts [6].

Additionally, the location of communities along rivers and coastlines can result in waste accumulating in the sea. In the natural surroundings, plastic waste breaks down into tiny microplastic particles measuring less than 5 mm [7]. These minuscule particles, due to their small size, long-lasting nature, and widespread prevalence, can be readily scattered, assimilated into ecosystems, and find their way into the human body. Researchers [8] successfully identified microplastics in the stool samples and everyday items collected from a fishing community residing in the coastal regions of Indonesia. Microplastics were found in human feces, indicating unintentional consumption from various origins. [9]. Community-based cleanup projects in rural areas can mitigate the volume of plastic waste that enters rivers and oceans. By engaging and educating local communities about the harmful effects of plastic pollution, we can create positive environmental outcomes while enhancing these communities' well-being. However, this vulnerability also presents an inherent incentive. Residents of these communities must directly profit from the cleanup efforts. Projects offering supplementary benefits, such as training, secure working environments, and financial incentives for handling waste, further enhance the community's ability to engage in sustainability initiatives [10, 11, 12].

The industry producing fuel oil from plastic waste has vast potential for development in Indonesia. Plastic waste has become a widely debated environmental issue in the era of globalization. Nearly all sectors of society have come to acknowledge the hazards of environmental damage, including the pollution caused by the accumulation of waste from daily human activities [13]. These plastic residues pose a notable and adverse environmental impact, damaging soil characteristics, negatively impacting soil microorganisms, and potentially infiltrating the human food chain (Salama and Geyer, 2023). The increasing production of plastics for various purposes has led to significant waste collection. The distribution of plastic waste is closely linked to the size of the human population. Pyrolysis of plastic waste fuel oil technology has the potential to utilize local and site-specific resources, providing economic benefits and job creation [15].

Additionally, it can support the productivity of the agricultural sector (by powering agrarian machinery), fisheries sector (by powering fishing boats), and small industry sector (including farm women groups and food MSMEs). However, regulatory inadequacies hinder the adoption of the pyrolysis process for converting plastic waste into fuel oil in Indonesia. This pyrolysis process will undoubtedly impact the environment, such as air, soil, and water quality changes. To reduce pollution and environmental impacts caused during fuel production, the proper method to analyze is the Life Cycle Assessment (LCA) method [16]. The objective of this analysis is to assess the ecological load resulting from an inventory analysis of resource utilization, fuel consumption, energy consumption, water usage, and other factors in order to determine the environmental consequences. Then, an investigation will be carried out using different alternative LCAs to reduce the effect caused [17, 18, 19, 20, 21]. Implementing circular economy principles can be one potential set of mitigation strategies [22].

Empirical evidence from Bank Sampah Banjarnegara (BSB) demonstrates the capacity of local communities to convert plastic waste into fuel oil. Under Article 17, Paragraph (1) of the Waste Management Law, a permit is mandatory for waste management. Bank Sampah Banjarnegara plays a crucial role in converting

plastic waste into valuable products, notably fuel oil. Challenges arise when the finished product, fuel oil, is subject to Article 54 of the Oil and Gas Law. While waste reduction involves limiting the generation of waste, the objective of the Waste Management Law (Article 20 Paragraph (1)) is to promote waste recycling and reusing. The responsibilities of the government and local authorities concerning converting plastic waste into fuel oil, per the Waste Management Law, are extensive. These include establishing targets, promoting eco-friendly technologies, and developing products that are advantageous to the community and can be commercialized to ensure regional energy self-sufficiency (Article 19 Paragraph (2) B of the Oil and Gas Law).

Regulations governing the conversion of plastic waste into diesel fuel oil are stipulated in specific legislation, namely, the Oil and Gas Law of 2001 (Law Number 22), which addresses matters related to oil and gas. The fundamental premise underpinning the Oil and Gas Law revolves around the strategic nature of oil and gas as non-renewable resources, which are under state control and play a significant role in the national economy. The management of these resources should facilitate the prosperity and welfare of the people. Indonesia's oil and gas business sector generates genuine value addition and supports sustainable, long-term economic growth [23]. Considerations from both national and international perspectives regarding changes in legislation surrounding oil and gas mining aim to establish oil and gas business operations that are autonomous, dependable, open, competitive, efficient, and eco-friendly while also stimulating the development of local potential and accountability. Due to the strategic significance of oil as a non-renewable natural resource, its management authority lies with the state [24] as stated in Article 33, Paragraphs 2 and 3 of the 1945 Constitution, "The land, water and natural resources shall be under the state's control and utilised for the people's greatest prosperity. The state is responsible for controlling the production sectors that are crucial and have an impact on people's livelihood." Indonesia's oil regulation policy is based on the principles of social-ecological justice. Social justice entails access to welfare in a societal framework, establishing the foundation for ecological justice implementation. To preserve critical natural capital for human interest, a socially and ecologically just society is required; as per Andrew Dobson [25], the linkage between social justice and environmental justice is that social justice has a function in supporting the maintenance and sustainability of development. Specifically, social justice combats poverty, which, in turn, positively affects the environment and increases its sustainability [26].

The responsibility of the government or local authorities in waste management is to aid in the implementation of locally-specific technologies developed by communities to manage and diminish waste (Article 6 Point f, Waste Management Law). Bank Sampah Banjarnegara (BSB) presents empirical evidence depicting community groups' ability to convert plastic waste into fuel oil. Budi Trisno Aji, the Chairman of BSB, created a tool that effectively processes plastic waste into fuel oil. Under Article 17 Paragraph (1) of the Waste Management Law, a license is necessary for waste management. Bank Sampah Banjarnegara is licensed to convert plastic waste into fuel oil, a helpful product. However, challenges arise when distributing the processed fuel oil to the Banjarnegara Regency community due to criminal consequences outlined in Article 54 of the Oil and Gas Law for fuel oil counterfeiting and imitation.

The Banjarnegara Regency Government has the authority to determine management policies and strategies based on national and provincial policies, to organise waste management at the district/city level by norms, standards, procedures and criteria set by other parties, to locate temporary shelters, integrated waste management sites and final treatment sites, to conduct regular monitoring and evaluation every 6 (six) months for 20 (twenty) years of closed open dump absolute treatment sites, and to establish and organise a waste management emergency response system by its authority (Article 9 of the Waste Management Law). The Banjarnegara Regency Government assists BSB in obtaining a permit to process, distribute, and use fuel oil processed from plastic waste. The government is committed to waste reduction, including curbing waste generation and recycling and reusing waste, as stipulated in Article 20, Paragraph (1) of the Waste Management Law. Considering the provisions regarding regional government waste management

obligations, the Banjarnegara Regency Government is obliged to support the conversion of plastic waste into fuel oil. This support includes goal setting, assistance with implementing environmentally friendly technologies and promoting responsible marketing of processed products, all aimed at realising the goal of eliminating plastic waste and promoting energy self-sufficiency in the region. (as outlined in Article 19, Paragraph (2) B of the Oil and Gas Law).

Bank Sampah Banjarnegara is a community located in a regency of Central Java Province, which has excellent potential for developing a pyrolysis business of fuel oil from plastic waste with the advantage of the availability of garbage in urban areas. Environmental sustainability is a significant concern due to the substantial amount of plastic waste generated and the insubstantial amount of recycling accomplished. A study conducted by Unilever Indonesia in collaboration with Sustainable Waste Indonesia (SWI) and Indonesian Plastic Recyclers (IPR) on the plastic waste value chain on Java Island has revealed alarming results. The research carried out from October 2019 until February 20, 2020, found that the urban communities in Java Island generate an estimated 189,000 tonnes of plastic waste per month, equivalent to 6,300 tonnes per day. Only approximately 11.83% or 22,000 tonnes per month of this volume are collected and recycled, with the remaining 88.17% being transported to landfills or dispersed in the environment. The uptake of post-consumer plastic waste in Java remains considerably low at only 0.09 million tonnes per annum, much less than the national plastic recycling capacity, which stands at approximately 1.65 million tonnes per year. One of the essential findings of this research shows that scavengers accounted for 83% of the about 22,000 tons of plastic waste collected. The Integrated Waste Management Site (TPST) or 3R Waste Management Site (TPS3R) contributed 15.2%, while the Waste Bank only contributed 1.5%.

The minor role of waste banks above shows that there is still room to increase the part of waste banks as one of the key players in mitigating the impact of post-consumer waste. One example of a company involved in converting plastic waste to fuel oil via pyrolysis is the Village Business (UD) Sampah Banjarnegara (BSB) Bank. BSB is a youth organisation that manages waste and preserves the environment. Established in 2015, they recognise the significant concern posed by the accumulation of plastic waste and the importance of immediate action. The younger generation needs to know how to process plastic waste into something useful to ensure the sustainability and carrying capacity of the environment under the current climate change conditions. BSB is situated in Kasilib Village, Wanadadi District, Banjarnegara Regency, Central Java Province, and is a recognised hub for training activities and comparative studies of waste banks in Indonesia. The Waste Bank's management and operational system resembles traditional banking, focusing on depositing and saving waste instead of currency. Currently, the Waste Bank serves over 8,000 customers from 25 villages spanning the Wanadadi, Punggelan, Rakit, and Bawang Districts.

BSB was formed to address the waste issue in Kasilib Village. The Waste Bank's presence has resolved the problem, resulting in a cleaner and more hygienic environment. In addition to its social impact, the Banjarnegara Waste Bank has generated revenue. However, it is currently impossible to determine the break-even point and profit, as the Cost of production still needs to be discovered. BSB still needs to assess the economic value of manufacturing fuel oil from plastic waste. BSB relies solely on profit-based production methods, resulting in profits that are not consistently maximised and thus fluctuate [27].

Consequently, the precise break-even point for producing Fuel Oil from Plastic Waste remains to be determined. Using the break-even point (BEP) analysis is suitable for optimising profits and advancing BSB's Plastic Waste Fuel Oil Production in the future. BEP is a tool that evaluates the scenario where the level of income and capital employed to generate gains is identical. Previous studies have implemented break-even points to determine profits in areas such as hotel management [28], tomato farming profits [29], and profits in salted fish businesses [30]. Cost analyses and production timetabling additionally bolster these findings [31], [32]. Various investigations have explored the composition and advantages of Fuel Oil from Plastic Waste [33, 34, 35, 36, 37, 38, 39, 40].

The purpose of this research is to support the advancement of sustainable energy development through the utilization of waste, along one or more dimensions of sustainability – environmental, economic, and social. Quantitative accounting of environmental impacts using Life Cycle Assessment sustainability measurement methods, and assessment of energy policies and measures that enable development in community-based areas with better governance. Measurement of economic profit using the break-even value (Zero Profit Point) in the Production of Fuel Oil from Plastic Waste at the Banjarnegara Waste Bank (BSB).

## 2. Methods

### 2.1. Location and Objects

This research was conducted at the Village Business (UD) Bank Sampah Banjarnegara (BSB) in Banjarnegara Regency, Central Java Province, Indonesia. The study focuses on producing fuel oil from plastic waste and is solely conducted to assess the business's economic aspects.

### 2.2. Data Collection Methods

The data collection method involved directly observing the production and operational activities and conducting interviews with business proprietors and employees at the Banjarnegara Waste Bank (BSB) enterprise.

### 2.3. Research Procedures

The research process will outline the various stages or phases undertaken in the study. This research's process is visually depicted in Figure 1.

### 2.4. Data Analysis

In this study, the data processing is carried out in several stages to obtain the break-even point (BEP) value, i.e.:

#### 2.4.1. Determination of Variable Costs (VC) and Fixed Costs (FC).

Variable costs encompass the cost of raw plastic waste materials and variable overheads, while fixed expenditures encompass direct labor, equipment, overheads, and other fixed costs.

#### 2.4.2. Calculation of total cost and total revenue.

The total cost signifies the monetary outlay required to acquire assets, while total revenue corresponds to the product's unit price multiplied by the quantity of products sold. Total Cost is calculated using Equation (1), and total revenue is calculated using Equation (2)

$$TC = FC + VC \quad (1)$$

Description:

TC = Total Cost

FC = Fixed Cost

VC = Variable Cost

$$TR = p \times q \quad (2)$$

Description:

TR = Total Revenue  
p = Price  
q = Quantity

2.4.3. *We are measuring the break-even point (BEP).*

To determine the break-even point of the placed capital. The BEP that will be calculated in this study is BEP Rupiah and BEP Units or the amount that can be sold to break even. BEP is calculated using equations (3) and (4).

$$\text{BEP Unit} = \text{FC} + \text{VC} = c \times n \quad (3)$$

$$\text{BEP Rupiah} = c \times n \quad (4)$$

Description:

TC = Total Cost

FC = Fixed Cost

c = Price

n = Quantity at BEP

2.4.5. *Assessment using software Open Life Cycle Assessment (LCA) also in terms of the environmental impact of the whole life cycle of a product produced by the business.*

The purpose of conducting LCA for the Plastic Waste Fuel production process is to measure its environmental impact and provide an in-depth understanding of how it affects the environment. Two methods were employed in the Assessment, namely, CML-IA Baseline and ReCiPe 2016 Midpoint (H), using the ecoinvent database. The CML-IA Baseline was selected to provide an overview of environmental impacts at a specific time and to concentrate on changes that occur over a short period. In contrast, ReCiPe 2016 Midpoint (H) was chosen for its complexity in combining multiple environmental impact indicators into a comprehensive analytical framework.

## 5. Research Procedures

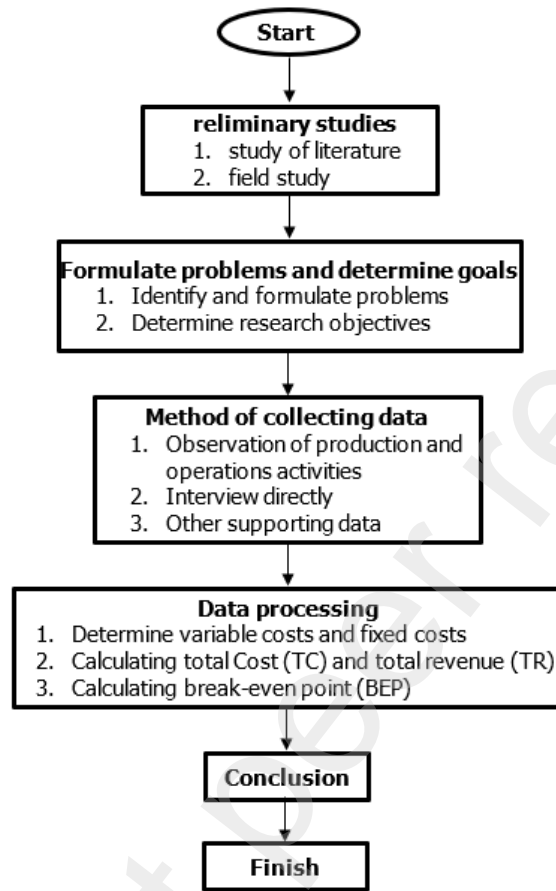


Figure 1. Research Procedure

## 3. Results

In this section, the results and discussion will progressively outline the costs that need to be known to calculate total costs, total revenue, and the break-even point. The expenses that need to be identified include variable and fixed costs. The findings and discussion are presented below.

### 3.1. Determination of Variable Cost (VC) and Fixed Cost (FC)

#### 3.1.1. Variable Cost

The variable costs will provide preliminary information that influences the overall costs incurred, encompassing factors such as the amount and cost of raw materials, as well as variable overhead expenses. In Table 1 below, can find details regarding the volume and value of waste plastic raw materials sourced from BSB.

Table 1. Raw material quantities and costs

No	Raw Material	Quantity/year (Kg)	Price (Rp)	Cost/year (Rp)
1	Plastic waste	31.200	2.000	62.400.000
	Total			62.400.000

Source: Banjarnegara Garbage Bank, 2023.

These variable overhead costs include the Cost of fuels such as firewood, kerosene (obtained from pyrolysis residues), charcoal/coconut shells, water, and electricity. The Cost of firewood, assuming use for one month (26 working days), is 4 m<sup>3</sup>, with a unit price of £3.38; thus, the annual Cost of using firewood is £1,047.52. The assumed Cost of kerosene is £0. The Cost of using 0.5 liters per day of 8,500 per liter fuel amounts to £73.49 per year. Charcoal made from carbon necessitates a daily initial combustion of 3 kilograms, costing approximately £1.05 per kilogram, resulting in a yearly total expense of £1,135.25. When factoring in a monthly fee of £27.64 for water and electricity, the annual charge amounts to £331.68. For variable overhead costs, please consult Table 2.

**Table 2.** Variable Overhead Costs

No	Inputs	Cost/year (Rp)
1	Firewood	3.120.025
2	Kerosene	1.326.000
3	Carbon charcoal	1.872.000
4	Water	600.000
5	Electricity	600.000
Total		7.518.025

Source: Banjarnegara Garbage Bank, 2023.

The total cost of raw materials incurred annually is Rp. 62,400,000, derived from using plastic waste raw materials, assuming the price of Rp. 2,000/kg and consumption of 100 kg per day, resulting in a total usage of 624,000 kilograms of plastic waste raw materials per year. Table 2 displays the variable overhead cost component, amounting to Rp. 7,518,025 per year. Therefore, the total variable Cost, obtained by adding the raw material and variable overhead costs, equals Rp. 69,918,025 annually. Table 3 below outlines the entire variable expenses comprising raw material costs and the variable overhead costs.

**Table 3.** Variable Costs

No	Cost types	Total cost/year (Rp)
1	Raw material	62.400.000
2	Overhead variable	7.518.025
Total		69.918.025

Source: Banjarnegara Garbage Bank, 2023.

### 3.1.2. Fixed Cost

Fixed costs will supply initial information that will impact the production cost of fuel oil from plastic waste. This category includes direct labor, equipment, overhead, and various other fixed expenditures. [41].

- Direct Labor Cost
- Direct labor is essential in all production processes. This study refers specifically to the labor involved in production and maintenance sections. Labor costs are calculated based on the assumed HOK cost of Rp. 75,000 for 8 hours of work by two workers. The assumed value of HOK costs means monthly labor costs of Rp. 3,900,000, and an annual fee of Rp. 46,800,000. Tables 4 and 5 exhibit the direct labor expenses incurred in the manufacturing process and the expenditures related to vehicle land rent and maintenance.

**Table 4.** Direct Labour Cost of Production Division

No	Activities	Total	Cost/month (Rp)	Total cost/year (Rp)
1	Production process	Two labors	3.900.000	46.800.000
Total				46.800.000

Sumber : Bank Sampah Banjarnegara, 2023.

Land rental costs are considered fixed costs since they do not affect the amount of production directly. The amount of production is influenced by raw materials and other inputs included in the variable cost section. Strategic location and easy transport access usually affect land rental costs [42]. The monthly cost of land rental is Rp. 1,250,000, resulting in a total of Rp. 15,000,000 per year, or a daily land cost of Rp. 48,077.

**Table 5.** Land Rental Costs

No	Cost	Maintenance Type	Cost/month (Rp)	Total cost/year (Rp)
1	Land Rental	Routine	1.250.000	15.000.000
Total				15.000.000

Source: Banjarnegara Garbage Bank, 2023.

- **Equipment Cost**

Equipment is necessary to support production and avoid potential delays and losses. Each piece of equipment undergoes depreciation, resulting in a yearly price decrease [43]. For this study, equipment depreciation is calculated at a fifty per cent decrease in value annually. Table 6 summarises the costs of the equipment.

**Table 6.** Equipment Cost

No	Equipment Types	Total	Total equipment price (Rp)	Depreciation/year (Rp)
1	Pyrolysis Machine Gen 5	1 unit	175.000.000	87.500.000
2	Octan Analyst	1 unit	6.000.000	3.000.000
3	Plastic holder	5 unit	250.000	125.000
4	Aluminum Sump	3 unit	250.000	125.000
5	Glass Bottle	5 unit	100.000	50.000
6	Small bucket	3 unit	30.000	15.000
7	Masks, gloves, shoes, clothing/equipment K3	1 packet	300.000	150.000
8	Scales & Other Measuring Instruments	1 unit	1.500.000	750.000
9	Pompa air	1 unit	400.000	200.000
Total				91.915.000

Source: Banjarnegara Garbage Bank, 2023.

- **Overhead Cost**

Overhead costs comprised land rental expenses (refer to Table 5) and equipment costs (refer to Table 6) in this study. The overhead costs are illustrated in Table 7 below.

**Table 7.** Overhead Cost

No	Cost type	Biaya Overhead (Rp)
1	Land Rental Cost	15.000.000
2	Equipment Cost	91.915.000
Total		106.915.000

Source: Banjarnegara Garbage Bank, 2023.

- Other Fixed Cost

BSB incurs other monthly fixed costs, such as indirect labor, vehicle depreciation, vehicle tax, administration, and marketing costs.

1. Indirect Labor Costs

Indirect labor comprises the workforce that operates beyond direct delivery [44]. Table 8 will present the costs incurred by indirect labor.

**Table 8.** Indirect Labour Cost

Work	Total	Monthly fees (Rp)	Total Cost per year (Rp)
Driver / Maid	One person	1.000.000	12.000.000
	Total		12.000.000

Source: Banjarnegara Garbage Bank, 2023.

2. Vehicle

The Bank Sampah Banjarnegara (BSB) possesses a 2010 Fortuner car bought for Rp. 160,000,000. The vehicle has a lifespan of twenty years with a monthly depreciation value of Rp. 666,000 and a total annual value of Rp. 8,000,000.

3. Vehicle Tax Cost

Vehicle tax expenses are part of the fixed costs that the company must bear annually. The company has to pay a total of Rp. 3,000,000 per year for taxes, which amounts to Rp. 250,000 per month.

4. Administration and Marketing Cost

Administrative and marketing costs impact the final product price [45]. Please refer to Table 9 for a detailed executive and marketing expenses breakdown.

**Table 9.** Administration and Marketing Costs

No	Needs	Cost per month (Rp)	Total Cost per year (Rp)
1.	Telepon/Handphone	50.000	600.000
2.	Office Stationery	50.000	600.000
	Total		1.200.000

Source: Banjarnegara Garbage Bank, 2023.

The total fixed costs also encompass overhead costs and other fixed costs [46]. Table 10 displays a breakdown of the total fixed costs.

**Table 10.** Total Fixed Cost

No	Cost Type	Total Cost Per Year (Rp)
1.	Cost of Direct Workers of Production Parts	46.800.000
2.	Land Rental Cost	15.000.000
3.	Equipment Cost	91.915.000
4.	Indirect Labor Costs	12.000.000
5.	Vehicle depreciation	8.000.000
6.	Vehicle Tax Fees	3.000.000
7.	Administration marketing costs	1.200.000
	Total	177.915.000

Source: Banjarnegara Garbage Bank, 2023.

Table 11 below will display the Total Fixed Costs and Variable Costs at Bank Sampah Banjarnegara (BSB).

**Table 11.** Total Fixed Cost and Variable Cost

No	Cost Type	Total Cost Per Year (Rp)
1	Fixed Costs (FC)	177.915.000
2	Variable Costs (VC)	69.918.025
	Total	247.833.025

Source: Banjarnegara Garbage Bank, 2023

The following table 12 will display the production of Fuel Oil from Plastic Waste at Banjarnegara Garbage Bank (BSB).

**Table 12.** Total Production of Fuel Oil from Plastic Waste at Banjarnegara Garbage Banks (BSB) Product

	Total Production per year (liter)	Sale price per litre (Rp)
Plastic Waste Fuel Oil	31.200	9.500

Source: Banjarnegara Garbage Bank, 2023.

### 3.2. Calculation of Total Cost (TC) and Total Revenue (TR)

Acquiring assets through economic sources involves sacrificing financial resources, which can be quantified in monetary units and are used to achieve predetermined objectives [47]. In contrast, total revenue is calculated by multiplying the product price per unit by the number of products sold. Production managers typically aim to enhance product sales to boost total revenue. The total cost and revenue calculation outcomes are presented below [31].

$$TC=FC+VC \quad (1)$$

$$TC=Rp\ 177.915.000+Rp\ 69.918.025$$

$$TC=Rp\ 247.833.025$$

$$TR=p \times q \quad (2)$$

$$TR=Rp\ 9.500 \times 31.200\ \text{liter}$$

$$TR=Rp\ 296.400.000$$

#### 3.1.1. Variable Cost

### 3.3. Break-even Point Calculation (BEP)

The Break-even point (BEP) is where revenue and costs are in equilibrium, resulting in no profit or loss [48]. It enables a business to forecast the units produced and the corresponding capital required to achieve BEP. Besides technical considerations, economic aspects, such as input expenses, are critical when generating fuel oil from recycled plastic in a profit-driven way. BEP analysis is an analytical tool that can assist in this regard [49,50,51]. The Calculation of BEP in this study comprises two components, namely BEP Unit and BEP Rupiah. Price BEP analysis determines the minimum production units required to achieve BEP conditions, while Price BEP establishes the minimum price per unit necessary to achieve BEP conditions in Rupiah units. Equation (3) is employed to calculate BEP units, while BEP Rupiah is computed using Equation (4). The BEP calculation yields the ensuing results [31].

$$BEP\ Unit=FC+VC=c \times n \quad (3)$$

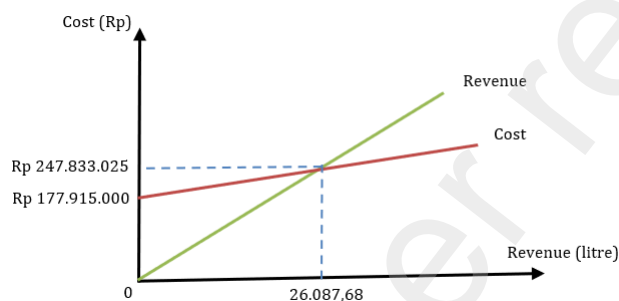
$$Rp\ 177.915.000 + Rp\ 69.918.025 = 9.500 \times n$$

$$247.833.025 = 9.500 \times n$$

$$n = 26.087,68\ \text{liter}$$

$$\begin{aligned} \text{BEP Rupiah} &= c \times n & (4) \\ \text{BEP Rupiah} &= \text{Rp } 9.500 \times 26.087,68 \text{ liter} \\ \text{BEP Rupiah} &= \text{Rp } 247.833.025 \end{aligned}$$

According to Equation (3), the Production BEP value equals 26,087.68 liters, while Equation (4) yields a Rupiah BEP of Rp 247,833,025. Research by [52] explored the profit generated by plastic waste fuel businesses within a year. Based on the analysis, a profit of \$300,917.51 was obtained per annum, which was not derived through BEP analysis. This study employs BEP analysis, using total Cost and price variables. Figure 2 shows the Break-Even Point (BEP) for producing Fuel Oil from Plastic Waste at Bank Sampah Banjarnegara (BSB). The graph depicts the cost and production volumes relationship, determining the revenue and cost curves that converge at the BEP.



**Figure 2.** Break-Even Point of Fuel Oil from Plastic Waste at Banjarnegara Garbage Bank (BSB)

The viability of producing fuel from plastic waste is assessed through a techno-economic appraisal [42], making this study a crucial component. Using the BEP calculation outlined in Figure 2, it can be deduced that BSB would need to sell 26,087.68 liters of Plastic Waste Fuel Oil annually to generate a turnover of Rp. 247,833,025 per year. Assuming an average monthly sale of 2,173.97 liters of Plastic Waste Fuel Oil, the payback is expected in the 12th month. From the 13th month onwards, BSB will earn a net profit.

### 3.4. Assessment Using Software Open Life Cycle Assessment (LCA)

Gate Fee, Unit pyrolysis cost, and Core system cost [16] are key parameters that affect net profit and will indicate the feasibility of the plastic waste fuel oil business. BSB must augment its investment value by procuring additional production equipment to expand future production capacity. Moreover, ameliorating quality will amplify the selling price of Plastic Waste Fuel Oil [53, 54].

The feasibility of a business should be assessed in terms of its economic potential in terms of production, revenue, and profit and the environmental impact of the whole life cycle of a product produced by the business. This Assessment can be done using a Life Cycle Assessment (LCA) [55]. The purpose of conducting LCA for the Plastic Waste Fuel production process is to measure its environmental impact and provide an in-depth understanding of how it affects the environment. However, it does not necessarily directly relate to social or economic impacts [56].

Two methods were employed in the Assessment, namely, CML-IA Baseline and ReCiPe 2016 Midpoint (H), using the ecoinvent database. The CML-IA Baseline was selected to provide an overview of environmental impacts at a specific time and to concentrate on changes that occur over a short period. In contrast, ReCiPe 2016 Midpoint (H) was chosen for its complexity in combining multiple environmental impact indicators into a comprehensive analytical framework [57].

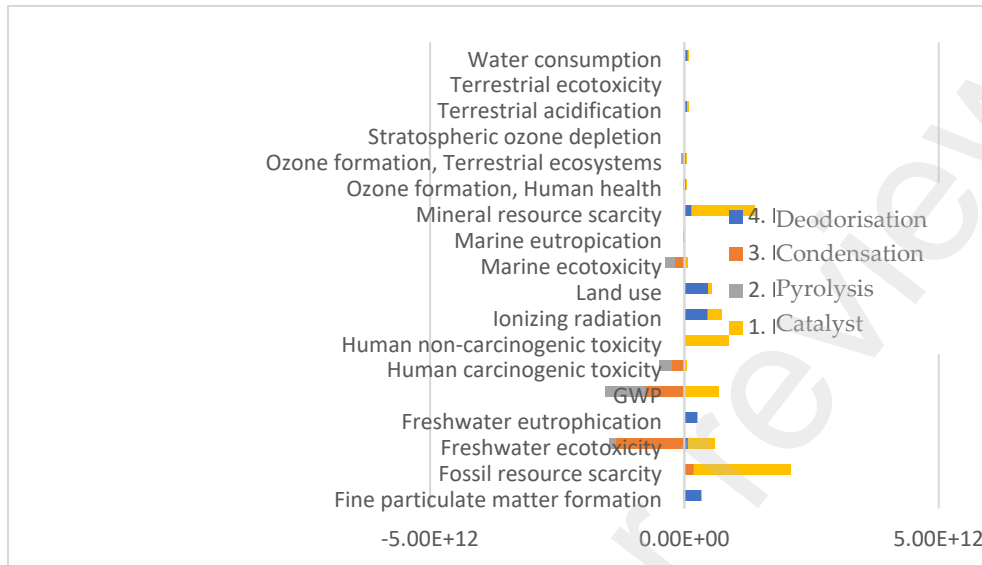
Based on the findings of the LCA examination utilizing the CML-IA Baseline technique conducted on this business cycle, it is demonstrated that the creation of Plastic Waste Fuel yields minimal air emissions during the pyrolysis procedure, making this business activity environmentally insignificant [58, 59, 60]. Further information is displayed in Table 13.

**Table 13.** Results of Impact Standard Analysis on Sustainable Plastic Waste Management into Liquid Fuel for Energy-Independent  
ence in Rural Areas

Impact Category	Total	Conclusion	Standard
<i>Ozone Layer Depletion</i>	3.09264E-08 kg Sb eq	The score obtained for the ozone layer is small and not at risk or safe.	Environmental Protection Agency (EPA) acceptable 1E-4.
<i>Fresh Water Aquatic Ecotoxicity</i>	0.966 kg 1,4-DB eq	The values obtained for Fresh Water Aquatic Ecotoxicity do not affect water pollution.	PP No 82 Year 2001 water pollution index value if < 0 IP < 1.0 does not affect the pollution of water
<i>Acidification</i>	0.000612 kg SO2 eq	Acidification in low conditions	Based on Prayitno (2017) on the Trox index (TRIX), if TRIX is less than 4, then Acidification is low.
<i>Eutrophication</i>	0.009 kg PO4- eq	Eutrophication in low conditions	Based on Prayitno (2017) on the Trox index (TRIX), Eutrophication is low if TRIX is less than 4.
<i>Human Toxicity</i>	0.6802 kg 1,4-DB eq	The value obtained for Human Toxicity is significant and risky or unsafe.	Environmental Protection Agency (EPA) for Inhalation Risk Unit Water, which is 7.8E-6
	0.69133 kg CO2 eq	The value obtained is significant and risky or unsafe	Environmental Protection Agency (EPA) acceptable 1E-4.

The contribution tree is a valuable tool in LCA as it facilitates identifying and comprehending the numerous life cycle stages and their environmental impacts. This information can enable us to take more effective steps towards environmental sustainability [61, 62]. The Banjarnegara Plastic Fuel production process involves five stages: Pyrolysis, Condensation, Deodorising, Purification, and Filtering. In the production

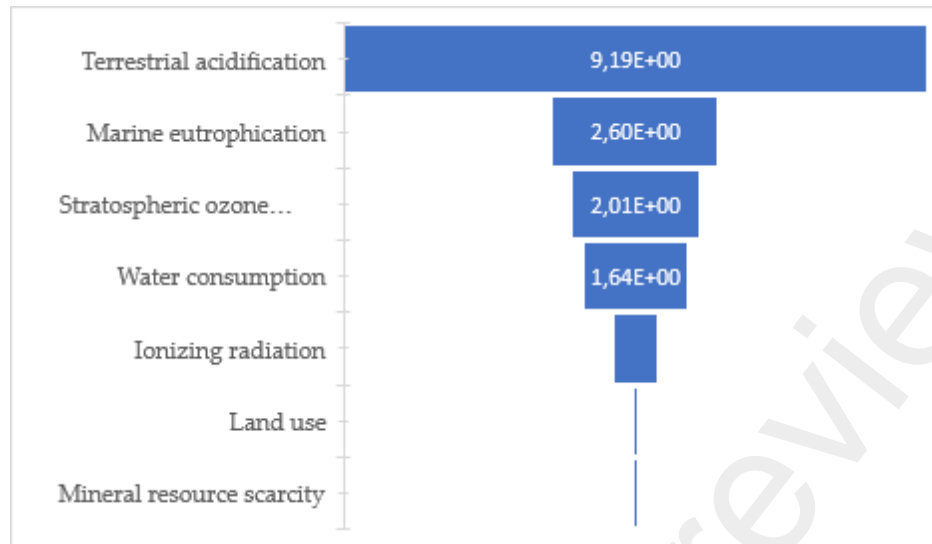
process, each step contributes to environmental impacts. Figure 3 presents the contribution tree of the Banjarnegara Plastic Fuel production process employing the ReCiPe 2016 Midpoint (H) method.



**Figure 3.** Contribution Tree of Banjarnegara Plastic Fuel Production Process

Figure 3 illustrates that out of the five stages of the Banjarnegara Plastic Fuel production process, four processes, namely odor removal, condensation, pyrolysis, and catalyst, impact the environment. Notably, the filtration process does not contribute to environmental impacts. The filtering process does not use electricity, so its contribution to the environmental effects is considered non-existent. The use of electricity during the production process impacts the environment. The use of coal fuel in the electricity production process has a significant effect on the environment [63, 64, 65]

[66] have emphasised the importance of normalisation and weighting in LCA comparative studies to aid decision-making. Normalisation and weighting are crucial in scenarios where alternate methods have superior environmental impacts in specific sectors but inferior impacts in other categories [67, 68, 69]. The effects of each reference value based on their location have been analysed to facilitate the interpretation of various impact indicators and create a single score for comparison between two or more technological options [70]. Following normalisation and weighting in the product system calculation, the top five contributions to environmental impact are presented in Figure 4.



**Figure 4. 5** Leading Contribution to the Environmental Impact of Plastic Fuel Production Process Banjar Negara

Based on Figure 4, the most significant contribution of environmental impacts is terrestrial Acidification, followed by marine Eutrophication, stratospheric ozone depletion, water consumption, and ionising radiation. The adverse effects of the pyrolysis process involve high heat and pressure, waste presence, and water usage [71, 72, 73, 74].

## 5. Conclusions

Based on the findings and discussions presented in this study, it can be concluded that the total production cost of pyrolysis of fuel oil from plastic waste at Banjarnegara Waste Bank in one year is Rp. 247,833,025. To break even, Bank Sampah Banjarnegara must sell 26,087.68 liters of plastic waste fuel oil. Four of the five stages of the Banjarnegara Plastic Fuel production process hurt the environment: deodorisation, condensation, pyrolysis, and catalyst.

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