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Implementation of AHP and Fuzzy Topsis Methods with Techno Economic Analysis Selection of Appropriate Technology for Waste Management Case Study University of Indonesia

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ABSTRACT: The "Zero Waste City" program is a waste management policy initiative in Depok City that has been implemented from 2016 to 2024. The primary objective of this program is to make the entire Depok City area free from all types of waste. However, the program's implementation faces challenges, leading to some areas in Depok City still struggling with waste issues. Universitas Indonesia, as a higher education institution located in Depok City, acknowledges the waste-related challenges in its surrounding environment. Therefore, the university is committed to actively participating in solving waste issues originating from its campus environment. This research aims to address waste issues at the source, particularly by applying appropriate technology based on the criteria and sub-criteria at Universitas Indonesia. This step is expected to contribute to reducing waste-related problems in Depok City and serve as an example of effective waste management from its source. Notably, Universitas Indonesia contributes to the accumulation of residual waste at TPA Cipayugn Depok, which has become increasingly concerning over time. The analysis in this study employs the Analytical Hierarchy Process (AHP) and Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) methods to evaluate suitable waste management technologies for addressing the issues of residual waste accumulation. Additionally, techno-economic analysis is conducted to assess the feasibility of the selected technology. The project's feasibility evaluation parameters include Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and Benefit Cost Ratio (BCR).

Keywords: AHP, Fuzzy TOPSIS, techno-economic analysis, waste management technology

INTRODUCTION

Waste management in cities, especially in higher education institutions such as universities, is a critical aspect in maintaining public cleanliness and health. The pile of garbage in the city, especially in higher education buildings, is an important issue because of the increasing amount of waste generated by daily activities. Waste that is not managed properly can be a source of environmental, health, and aesthetic problems. Higher education buildings, such as universities, are often centers of academic activities, research, and community service. Along with the intensity of these activities, the volume of waste produced can increase significantly. Therefore, effective and sustainable efforts are needed in managing waste piles in higher education buildings to prevent their negative impact on the environment and public health. The pile of garbage in higher education buildings is not only a responsibility of the campus environment itself, but also reflects social responsibility and concern for the wider environment. Therefore, research and innovation in the management of waste piles in higher education buildings are very important (Pramudiyanto & Suedy, 2020). This can include improving waste management infrastructure, applying technology, as well as education and awareness to maintain environmental cleanliness and sustainability. Generally, waste generation is dominated by organic waste. The University of Indonesia today is still a subscriber to dispose of residual waste to the Cipayung Depok Landfill, based on data collected from the Department of Operations and Facility Maintenance of the University of Indonesia, waste generation in 2024 will experience a significant spike and even reach 2 times from 2023, residual waste is waste that no longer has economic value or can no longer be recycled again, so that the waste will be transported to the Cipayung Depok Landfill, in this case the University of Indonesia is a contributor to the waste pile at the Cipayung Landfill which is increasingly dangerous (Qazi, Abushammala, & Younes, 2018). According to (Ministry of Environment and Forestry Library, 2019) the incoming waste in 2019 reached 1300 tons per day where the capacity of the Cipyaung Depok Landfill was only able to accommodate 800 tons per day. Based on data from the National Waste Management Information System in 2021 the Cipayung Depok Landfill has reached 362,810 -450,000 tons per year, there is a Leachate Water Treatment Plant (WWTP) at the Cipayung Landfill but it has been damaged or not functioning properly and is not terawatt, so that in the environmental aspect it can cause disaster. Depok City waste is mostly dominated by food waste of 62.95%, plastic 21.36% and 7.24% of other waste. (National Waste Management Information System, 2021).

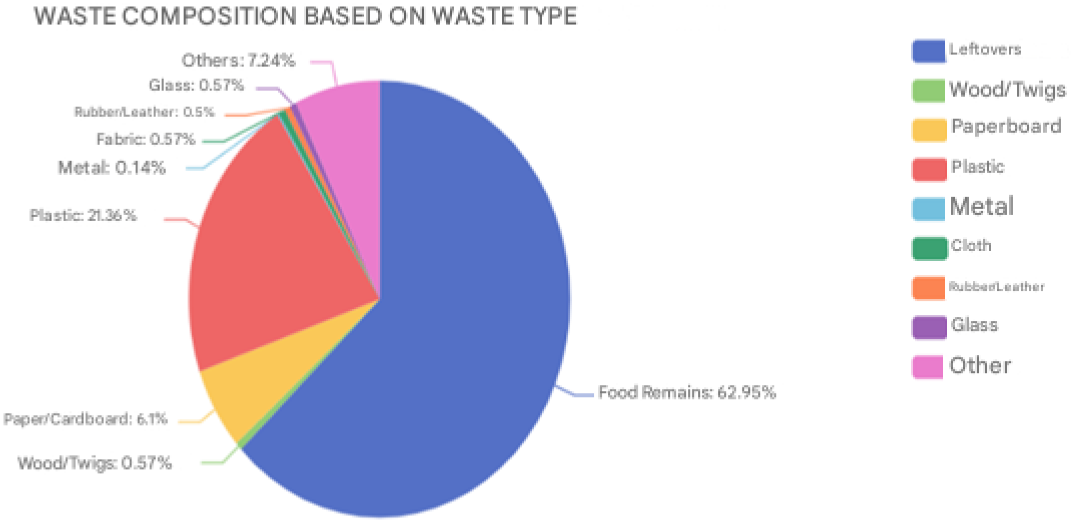

Figure 1. Types of waste composition in Depok City
(National Waste Management Information System, 2021).

(Silvia Shyfa Azani, 2023) stated that Depok City is ranked third in terms of the highest volume of waste in West Java, which is 1,418.87 tons/day in 2020. The Zero Waste City program is a waste management policy in Depok City that was implemented from 2016 to 2024. The main purpose of this program is to free all areas in Depok City from all types of waste, in fact it shows that there are problems in the implementation of waste management, so that some areas in Depok City have still not succeeded in being free from waste problems (Satiada & Calderon, 2021). The University of Indonesia is a higher education that administratively is located in the city of Depok, seeing the problems of existing conditions, it is appropriate for the University of Indonesia to take part in solving its own waste problem from UPS University of Indonesia, this research aims to solve the problem of waste from the source, especially with appropriate technology that is in accordance with the conditions of the criteria and subcriteria at the University of Indonesia so that it can helping to reduce waste problems in the city of Depok and becoming a pilot in managing waste from its source. To find out the appropriate technology that is suitable for analysis, this study uses the Analytical Hierarchy Process (AHP) & Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) method to find out the appropriate technology that is suitable for solving the problem of waste generation, technoeconomic analysis of the feasibility of investment in selected technologies is also carried out in this study to determine the feasibility of the project to be implemented with Net Present parameters Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and Benefit Cost Ratio (BCR).

Previous studies have explored various facets of the influence of technology on user behavior and content consumption patterns. For example, a study by Smith et al. (2021) investigates how algorithm-driven content delivery impacts user engagement on social media platforms. Their findings suggest that tailored content can increase engagement but also reinforce biases through echo chambers. Another study by Johnson and Lee (2022) delves into the rise of misinformation within user-generated content, highlighting how unchecked information dissemination has affected public perception and decision-making. Both studies underscore the dual-edged nature of algorithmic content delivery, which fosters engagement but also creates challenges in information quality and diversity.

The increasing reliance on algorithmic systems for content delivery, combined with the proliferation of user-generated content, necessitates timely research to understand the resulting implications. The rapid spread of misinformation, particularly among Generation Z, has raised concerns about its long-term societal impacts. This generation's distinctive media consumption habits, largely shaped by digital environments, make them more susceptible to echo chambers and misinformation. Thus, this research becomes urgent as it addresses these evolving issues and explores strategies for mitigating their effects, ensuring that future technological developments are aligned with the public’s well-being and informed decision-making.

While previous studies have examined the role of algorithms and user-generated content separately, this research introduces a novel perspective by combining these elements and focusing on their combined effects on Generation Z. The study uniquely addresses how algorithm-driven content and user-generated contributions interact to shape this cohort’s online experience, with a particular emphasis on misinformation and echo chambers. Moreover, it integrates emerging theories in digital media with user behavior studies, offering a fresh lens through which to analyze and understand current trends in social media engagement, misinformation, and content manipulation.

Despite the valuable insights from existing literature, there remains a significant gap in research that specifically examines the intersection of algorithmic content delivery and user-generated content, especially concerning Generation Z. Most studies focus on either one of these aspects but fail to combine them in the context of misinformation and echo chambers. Additionally, limited research has addressed the effectiveness of interventions aimed at breaking these echo chambers or correcting misinformation among younger, digital-native audiences. This study aims to fill these gaps by exploring the synergistic effects of both factors and proposing solutions to mitigate their negative consequences on public discourse.

The purpose of this study is to find out the relevant and important criteria and subcriteria in the selection of waste treatment technology at the University of Indonesia. Determine the priority weight, ranking, criteria and subcriteria in the selection of waste treatment technology at the University of Indonesia using the Analytic Hierarchy Process (AHP) method. Determine the priority of alternative ranking of waste processing technology at the University of Indonesia based on the criteria and subcriteria that have been determined by the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. Determine the feasibility of techno-economic investment from technology that will be applied at the University of Indonesia during the economic life of the selected technology

The benefit of holding this research is for academics, this research contributes to academic knowledge about waste management and waste reduction in cities. The use of AHP and Fuzzy TOPSIS methods in this study provides a real example of how decision analysis can be applied in the context of waste treatment technology selection. For technology development, the results of the research can be used as a reference to overcome the waste issue, where waste processing technology is a promising solution to realize sustainable development and overcome the landfill crisis and increase the economic benefits of waste. For the community, this research has a wide positive impact, both in terms of more effective waste management, reducing the adverse impact of waste heaps, and increasing welfare and environmental awareness. For the environment, this research plays an important role in protecting the environment and reducing the level of pollution due to solid waste in the city, as well as the use of green energy from waste and solutions to solve waste problems and reduce the burden of waste heaps which today are a crucial problem in landfills.

RESEARCH METHODOLOGY

The study employs a quantitative research design, integrating the Analytical Hierarchy Process (AHP) and the Fuzzy Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) to assess suitable waste management technologies at the University of Indonesia. Conducted in Depok City, West Java, the research involves key subjects including waste management staff, environmental technology experts, and students from relevant study programs. Data collection utilizes questionnaires to gather insights on criteria and sub-criteria for technology selection, supplemented by semi-structured interviews with experts for a deeper understanding of existing technologies and their challenges. Additionally, documentation regarding waste generation and management reports will support a comprehensive techno-economic analysis. This approach aims to yield valid and actionable data for selecting effective waste management solutions at the university.

RESULT AND DISCUSSION

Analisis Analytical Hierarchy Process

At this stage, all questionnaire data that has been collected are analyzed for weighting of the criteria and subcriteria of the assessment are calculated based on the existing formula and assisted by the Ms.Excel application, the following calculations are made in the AHP method:

1. Pairwaise Comparison Matrix

After making a hierarchy of decisions in figure 1, then make a pair comparison matrix, the matrix is made based on the results of the analysis questionnaire data, in the assessment of the relative importance of the two comparisons apply the reciprocal axiom if k1 is equal to 3 times k2 then automatically k2 is one-third of k1, in mathematical language if k1 = 3x k2 then k2 = 1/3 k1, if there is more than one decision maker then it is necessary to calculate the geometric mean using the equation (Statistik, 2019) :

Table 1. Paired Comparison Matrix

		Decision Maker-1		
	Technique	Economics	Milieu	Social
Technique	1,00	5,00	0,50	3,00
Economics	0,20	1,00	0,20	0,50
Milieu	2,00	5,00	1,00	5,00
Social	0,33	2,00	0,20	1,00
sum	3,53	13,00	1,90	9,50
		Decision Maker-2		
	Technical	Economics	Milieu	Social
Technical	1,00	0,20	0,14	0,50
Economics	5,00	1,00	0,20	2,00
Milieu	7,00	5,00	1,00	8,00
Social	2,00	0,50	0,13	1,00
sum	15,00	6,70	1,47	11,50
		Decision Maker-3		
	Technical	Economics	Milieu	Social
Technical	1,00	3,00	2,00	5,00
Economics	0,33	1,00	0,33	3,00
Milieu	0,50	3,00	1,00	3,00
Social	0,20	0,33	0,33	1,00
Sum	2,03	7,33	3,67	12,00
		Geometric Mean		
	Technical	Economics	Milieu	Social
Technical	1,00	1,44	0,52	1,96
Economics	0,69	1,00	0,24	1,44
Milieu	1,91	4,22	1,00	4,93
Social	0,51	0,69	0,20	1,00
Sum	4,12	7,35	1,96	9,33

2. Priority Weight (Eigenvector)

At this stage, the weight value of each criterion and sub-criterion is taken into account, the highest to lowest priority weight value will determine the priority of the ranking of alternative technologies to be selected and also the priority weight value will be ranked from the largest to the smallest which will describe the concentration of experts in choosing alternative technologies to be implemented, the determination of priority weights can be calculated by first normalizing the comparison matrix Normalized Pairwaise Comparasion using equation (Al Naami, 2017) to calculate priority weights using equation (Jaspi, Yenie, & Elystia, 2015):

Table 2 Priority Weight of criteria (Eigenvector)

			Decision Maker-1			
	Technical	Economics	Milieu	Social	Sum	Priority Weight
Technical	0,283	0,385	0,263	0,316	1,247	0,312
Economics	0,057	0,077	0,105	0,053	0,291	0,073
Milieu	0,566	0,385	0,526	0,526	2,003	0,501
Social	0,094	0,154	0,105	0,105	0,459	0,115
			Decision Maker-2			
	Technical	Economics	Milieu	Social	Sum	Priority Weight
Technical	0,067	0,030	0,097	0,043	0,237	0,059
Economics	0,333	0,149	0,136	0,174	0,793	0,198
Milieu	0,467	0,746	0,681	0,696	2,590	0,647

	Technical	Economics	Milieu	Social	Sum	Priority Weight
Social	0,133	0,075	0,085	0,087	0,380	0,095
Decision Maker-3						
	Technical	Economics	Milieu	Social	Sum	Priority Weight
Technical	0,492	0,409	0,545	0,417	1,863	0,466
Economics	0,164	0,136	0,091	0,250	0,641	0,160
Milieu	0,246	0,409	0,273	0,250	1,178	0,294
Social	0,098	0,045	0,091	0,083	0,318	0,080
Geometric Mean						
	Technical	Economics	Milieu	Social	Sum	Priority Weight
Technical	0,243	0,196	0,266	0,210	0,915	0,229
Economics	0,168	0,136	0,121	0,155	0,580	0,145
Milieu	0,465	0,574	0,510	0,529	2,076	0,519
Social	0,124	0,094	0,103	0,107	0,429	0,107

Table 3 Subcriteria Priority Weights (Eigenvector)

	DM-1	DM-2	DM-3	GM
Subkriteria	BP	BP	BP	BP
Efficiency Conversion	0,490	0,669	0,633	0,620
power generation	0,312	0,088	0,260	0,201
maturity	0,198	0,243	0,106	0,179
Cost of capital	0,312	0,487	0,581	0,459
o & m	0,490	0,435	0,309	0,418
Energy Costs	0,198	0,078	0,110	0,123
Emission	0,198	0,472	0,643	0,448
Potential Pollutants	0,312	0,444	0,283	0,387
Health Impact	0,490	0,084	0,074	0,165
Employment	0,490	0,090	0,595	0,347
Security	0,312	0,767	0,277	0,475
Social Acceptance	0,198	0,143	0,129	0,179

3. Ratio Consistency & Consistency Index (CI & CR)

Measuring logical consistency aims to find out whether the assignment of values by experts or respondents in making comparisons between elements has been done correctly consistent is not contradictory, the assessment is said to be consistent if the consistency ratio does not exceed 0.1 or 10%, to measure the consistency rate can be done by calculating the vector value A of the initial matrix multiplied by the priority weight can be calculated by equation (Chusna, Gunandito, Dermawan, & Ernawati, 2022) and calculating the vector value B using equation (Frear & Fuchs, 2006), calculating the Maximum Eigenvalue of equation (McDonald, Achari, & Abiola, 2008), measuring the Consitency Index (CI) with equation (Matheri et al., 2018) then calculating the Consistency Ratio (CR) with equation (Sawyerr, Trois, Workneh, Oyebode, & Babatunde, 2020) where the CI value is divided by the Random Index (RI) value based on the order n of the number of matrices in table 4, here are the calculation results below:

Table 4. Consistency Index & Consistency Criterion Ratio

Vektor A Decision Maker-1					
DM-1	Technical	Economics	Milieu	Social	Sum
Technical	0,312	0,364	0,250	0,344	1,270
Economics	0,062	0,073	0,100	0,057	0,293
Milieu	0,623	0,364	0,501	0,573	2,062
Social	0,104	0,146	0,100	0,115	0,464
Vektor B Decision Maker-1					
	Technical	Economics	Milieu	Social	Sum
	4,076	4,017	4,117	4,050	16,260
CI & CR Decision Maker-1					

E GV (ƛ Max)		THERE	CR	Indicator	
4,065		0,022	0,024	Consistent	
Vektor A Decision Maker-2					
	Technical	Economics	Milieu	Social	Sum
Technical	0,059	0,040	0,092	0,048	0,239
Economics	0,297	0,198	0,129	0,190	0,814
Milieu	0,415	0,991	0,647	0,760	2,814
Social	0,119	0,099	0,081	0,095	0,394
Vektor B Decision Maker-2					
	Technical	Economics	Milieu	Social	Sum
	4,028	4,109	4,346	4,143	16,626
CI & CR Decision Maker-2					
E GV (ƛ Max)		THERE	CR	Indicator	
4,157		0,0522	0,058	Consistent	
Vektor A Decision Maker-3					
	Technical	Economics	Milieu	Social	Sum
Technical	0,466	0,481	0,589	0,398	1,933
Economics	0,155	0,160	0,098	0,239	0,652
Milieu	0,233	0,481	0,294	0,239	1,247
Social	0,093	0,053	0,098	0,080	0,324
Vektor B Decision Maker-3					
	Technical	Economics	Milieu	Social	Sum
	4,150	4,069	4,234	4,078	16,532
CI & CR Decision Maker-3					
E GV (ƛ Max)		THERE	CR	Indicator	
4,133		0,0443	0,049	Consistent	
Vektor A *Geometric Mean*					
	Technical	Economics	Milieu	Social	Sum
Technical	0,229	0,209	0,271	0,210	0,919
Economics	0,159	0,145	0,123	0,155	0,581
Milieu	0,438	0,611	0,519	0,529	2,097
Social	0,117	0,100	0,105	0,107	0,430
Vektor B *Geometric Mean*					
	Technical	Economics	Milieu	Social	Sum
	4,017	4,010	4,040	4,009	16,076
CI & CR *Geometric Mean*					
E GV (ƛ Max)		THERE	CR	Indicator	
4,019		0,0063	0,007	Consistent	

From the results of the calculation above, the value of the consistency ratio is below 0.1 so that it can be concluded that it is consistent or valid, to find out the overall consistency ratio of the subcriteria, the summary table is presented below:

Table 5. Consitance Index & Consistency of Subcriteria Ratios

Subkriteria	DM-1	DM-2	DM-3	GM	Indicator
	CR	CR	CR	CR	
Efficiency Conversion					
power generation	0,046	0,006	0,033	0,011	Consistent
maturity					
Cost of capital					
O & M	0,046	0,010	0,003	0,008	Consistent
Energy Costs					
Emission					
Potential Pollutants	0,046	0,003	0,056	0,00014	Consistent
Health Impact					
Employment					
Security	0,046	0,047	0,005	0,014	Consistent
Social Acceptance					

4. Ranking Criteria and Subcriteria

From the weight of the Geometric Mean of the overall expert assessment that has been obtained in the calculation, then ranking is carried out based on the order of the largest global weight to the smallest weight, the global weight is obtained from the multiplication between the weight of the criteria and the weight of the subcriteria so that the criteria and subcriteria that are the priority of the assessment in determining alternative technologies that are suitable for waste processing at the University of Indonesia are known, The following is the priority ranking of the criteria and subcriteria in this BAAWAH in the table and graph:

Table 6. Ranking of priority criteria and subcriteria

Criterion	Weight	Rank	Subkriteria	Local Weight	Local Ranking	Global Weight	Global Ranking
Technical	0,229	2	Efficiency Conversion	0,620	1	0,142	3
			power generation	0,201	2	0,046	8
			maturity	0,179	3	0,041	9
Economics	0,145	3	Cost of capital	0,459	1	0,067	5
			O & M	0,418	2	0,061	6
			Energy Costs	0,123	3	0,018	12
Milieu	0,519	1	Emission	0,448	1	0,233	1
			Potential Pollutants	0,387	2	0,201	2
			Health Impact	0,165	3	0,085	4
Social	0,107	4	Employment	0,347	2	0,037	10
			Security	0,475	1	0,051	7
			Social Acceptance	0,179	3	0,019	11

From table 6, it can be seen that the weight of the highest environmental criteria with a value of 0.519 shows that environmental interests are the highest priority to determine alternative waste management technology considering that the University of Indonesia is an educational institution that has a role in reducing the level of air pollution which is a problem in Indonesia today. The Engineering criterion with a weight of 0.229 which gets the global ranking number 2, in addition to environmental factors, technical factors are also important to determine the reliability of the technology that will be used in the waste processing process in accordance with the characteristics of waste at the University of Indonesia, the 3rd rank is obtained by economic criteria with a weight of 0.145 and the 4th is obtained by social criteria with a weight of 0.107.

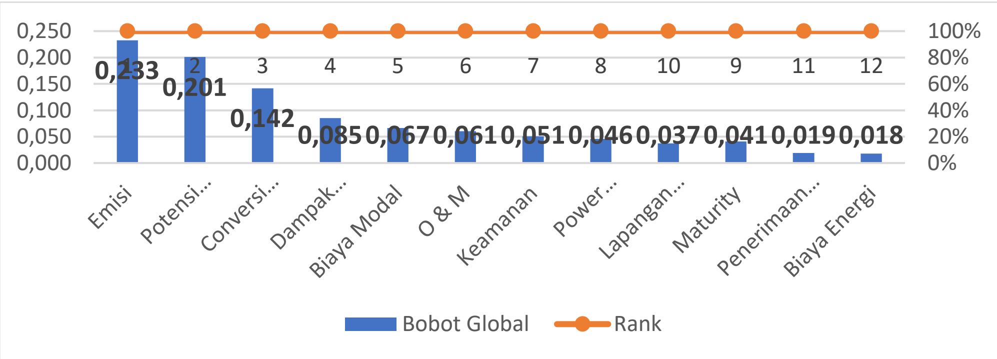

Figure 2. Global ranking & global weight subcriteria

It can be seen in figure 2 that the emission subcriteria get a rank of 1 global rank with a global weight of 0.233 and the potential pollutants get a second rank with a global weight of 0.201 This shows that the emission subcriteria and potential pollutants are a concern of the selection of technology that has a low emission rate and pollutants according to the characteristics of waste in Indonesian universities, followed by an efficiency conversion with a global weight of 0.142 is also needed technology that has a good efficiency conversion but do not forget the environmental aspect which is the most important level in the selection of technology, the health impact gets a weight of 0.085 It can be known together that the University of Indonesia is an academic community environment so it is necessary to pay attention to the effect of the health impact for the academic community, the cost of capital gets a global weight of 0.067 This makes a consideration to get a low cost of technology investment so that there are savings and returns a quick initial investment from the savings obtained.

Analisis Fuzzy Technique for Order Performance by Similarity to Ideal Solution

In the alternative technology selection stage, the data used is the opinion of experts who have given an assessment based on linguistic variables in table 2.11 and converted into the form of Fuzzy numbers, Expert assessments are arranged in the form of a comparison matrix between subcriteria to subsequently rank the opinions of experts for several alternative technologies that have been selected.

1. Matrix of Comparison of Technology Alternatives to Subcriteria
2. Matrix of Combining Technology Alternatives to Subcriteria
3. Weighted Decision Normalization Matrix
4. Technology Alternative Ranking

Biodigester Specification

At this stage, an analysis of the calculation of the methane gas produced and also the size of the reactor needed to distinguish the average data of organic waste generation in table 7 can be calculated, so that the economic value can be calculated and the investment capital cost that will be incurred is differentiated from the calculation of specifications in accordance with the existing conditions of waste generation.

1. Methane Gas Potential (CH4)

At this stage, the calculation of the potential of methane gas (CH4) produced from the generation of existing organic waste is carried out, the generation of existing waste will be processed with 3 reactor units, using equations (Al Naami, 2017) as follows:

Table 7 Average organic waste generation per day

	Organic (Kg)			Annual Average (kg)	Daily Average (kg)	3 Unit AD (kg/unit)
Year	2022	2023	2024			
TOTAL	47.364	94.385	117.645	86.465	237	79

Calculating the Total Solid (TS) value

$TS=27{,}7\% \times 79=21{,}9$ kg/H

Calculating the value of Volatile Solid (VS)

$VS=74{,}1\% \times 21{,}9$ kg/H$=16{,}2$ kg/H

Calculating the value of biogas production volume (VBS)

$VBS=0.676 \times 16{,}2$ kg/H$=11$ m3/H

Calculating the amount of methane gas

$VGM=60\% \times 11$ m3/H$=6{,}6$ m3/H

From the results of the calculation above, the potential of methane gas produced per reactor unit where the reactor is divided into 3 units, from the total organic waste generation per day of 237 kg will be processed using 3 units of biodigester rector with each reactor of 79 kg/H can produce 6.6 m3/H of methane gas (CH4) per reactor unit, the calculation results can be seen in the following table:

Table 8 Potential of existing methane gas

AD Reactor (Unit)	Organic (kg/day)	TS (kg/day)	VS (kg/day)	VBS (m3/day)	VGM/unit (kg/day)	VGM total (kg/day)
3	79	21,8	16,1	13,3	6,6	19,7

2. Geometri Reactor Biodigester (Anaerobic Digester)

After determining the potential of methane gas (CH4) produced from the generation of existing organic waste, the next step is to determine the geometry of the size per unit of the reactor in accordance with the potential for gas production produced, the required rector geometry parameters include the height and diameter of the rector adjusting to the volume of organic waste raw materials per day, the height and diameter of the dome adjusting to the daily gas production volume, The geometry of the reactor can be calculated using equations (5), (6), (7), and (8) as follows:

Calculating slury volume (Vs) HRT 30 days

$$Vs = 30\ (hari) \times \frac{2 \times 79\ (kg)}{1000} = 4{,}74\ m3$$

Calculating the height (H) & diameter (D) of the reactor

$$H = \left(\frac{4{,}74\ (m3)}{3{,}14}\right)^{\frac{1}{3}} = 1{,}15\ m$$

$$D = 2 \times 1{,}15\ (m) = 2{,}29\ m, r = 1.15\ m$$

Calculating the geometry of the production gas

$$Vtabung = (3.14 \times 1{,}15^2 \times 1{,}79) = 7{,}4\ m3$$

$$Vdome = \left(\frac{1}{6} \times 3{,}14 \times 1{,}25\right) \times (3 \times 1{,}15^2 + 1{,}25^2) = 3{,}6\ m3$$

$$Vd = 7{,}4 + 3{,}6 = 11\ m3 = VBS$$

Calculating the geometry of total methane gas storage

$$19{,}7\ m3 = 3.14 \times 1{,}5^2 \times h$$

$$h = \frac{19{,}7}{3{,}14 \times 1{,}5^2} = 2{,}8\ m$$

From the results of the calculation above, the geometry value used in making the rector is obtained, the following geometry parameter data in the table below:

Table 9 Parametr geometri biodigester

Parameter Geometri	Value
Production Gas (VBS)	11 m3/day
Gas Methane (VGM)	6.6 m3/ha
Volume Slury (Vs)	4.74 m3
Reactor diameter	2.29 m
Reactor height	1,15 m
High storage of production gas	1,79 m
High Dome Gas Production	1.25 m
Total CH4 Storage Height	2.8 m
Total CH4 Storage Diameter	3 m

Techno Economy Biodigester (Anaerobic Digester)

At this stage, the Biodigester (Anaerobic Digester) is calculated its economic value, starting from the initial investment cost, Net Present Value (NPV), Internal Rate of Return (IRR), Pay Back Period (PBP), and Benefit Cost Ratio (BCR).

1. Cost Aspects of Biodigester

Biodigester investment is based on the geometry of the assumed size based on the Blue biodigester price approach, the price of other system complements such as Methane Purifer, Storage Tank (CH4), Manometer, and Gas Generator are obtained from the marketplace and product reference of Kencana Online (PT Cipta Visi Sinar Kencana), there are installation costs and training costs that are assumed. The data is in the form of the table below

Table 10 Cost of biodigester investment (anaerobic digester)

Investment				
Kind	Price	Qty	Total	Information
Biodigester	IDR 17,000,000	3	IDR 51,000,000	refrence biodigester biru 2024(reaktor system consturksi + piping inlet pvc aw 4inch + piping gas SNI 07-0242.1-2000 galavanis 1,5" tebal 3mm)
Installation Services	IDR 6,000,000	1	IDR 6,000,000	
Training	IDR 2,000,000	1	IDR 2,000,000	
Manometer	IDR 200,000	7	IDR 1,400,000	
Methane purifer	IDR 10,000,000	3	IDR 30,000,000	D 12" T 135 cm (PT Cipta Visi Sinar Kencana)
CH4 Storage Tank	IDR 30,000,000	1	IDR 30,000,000	
Generator CH4	IDR 15,000,000	2	IDR 30,000,000	2500 w/4 hours/6 m3 ch4 (PT Cipta Visi Sinar Kencana)
Garbage Sorting Machine Auto	IDR 18,000,000	1	IDR 18,000,000	200-300 kg/hour (Madani Tech, tokopedia)
Unexpected	IDR 10,000,000	1	IDR 10,000,000	
Land	IDR 0		IDR 0	Land and buildings owned by UI
Building	IDR 0		IDR 0	
TOTAL			IDR 178,400,000	

From the table above, it can be seen that the total value of the initial investment cost is Rp.178,400,000,

Of course, in operating a Biodigester (Anaerobic Digster) requires operational and maintenance (O&M) costs, for the annual operation and maintenance costs are quite low for Biodigester technology, for assuming the detailed operational costs and maintenance are presented in table 11 below:

Table 11 Operational costs & biodigester maintenance

O&m					
kind	Qty	interval	Price/item	Price/Year	Information
Methane Refining Chemicals	2	6 months	IDR 1,500,000	IDR 3,000,000.00	4.4 kg dose/7m3 ch4 (kencana online)
Generator Oil	6	2 months	IDR 100,000	IDR 600,000	1 lter/ month
Unexpected	12	1 month	IDR 200,000	IDR 2,400,000	unexpected/Save
Labour & Transport	2	1 month	IDR 0.00	IDR 0.00	3rd party ui
Electricity	12	1 month	IDR 700,000	IDR 8,400,000	
PPE	2	6 months	R400,000	IDR 800,000	Masks Respirator
TOTAL				IDR 15,200,000	

2. Depreciation and Salvage Value Aspects of Biodigester

At this stage, the depreciation value of the biodigester technology is calculated by distinguishing the initial investment value and the economic life of the technology itself, the depreciation method used is the straight line method, and it is assumed that the salvage value is Rp.5,000,000 where at the end of the life of the biodigester technology system there is still a residual value obtained from the sale of the instrument system, from this assumption the annual depreciation of the Biodigester technology is obtained of Rp.8,670,000, For details of the depreciation value, which can be seen in table 12, depreciation can be calculated using the following equation (Marsono, 2020):

$$depresiasi = \frac{\text{Rp178.400.000} + Rp.5.000.000}{20\ tahun} = Rp\ 8.670.000\text{/year}$$

Table 12 Depreciation & salvage value biodigester

Depreciation				
Kind	Investment	Residual Value (SV)	Economical Life	Depreciation/Year
Biodigester	IDR 178,400,000	IDR 5,000,000	20 years	IDR 8,670,000

3. Aspects of Biodigester Cash Flow

To find out the cash inflow or net profit (Net Profit) that we receive, it is necessary to calculate between the cost of expenditure (O&M) and the cost of income, where the cost of income is obtained from the sale of electricity generated from the conversion of methane gas using a methane gas generator, for the price of the electricity tariff produced adheres to the Regulation of the Ministry of Energy and Mineral Resources No. 27 of 2014, the potential production of 19.7 m3 of methane gas per day is equivalent to 184,983 Kwh, with a total annual revenue from electricity sales of Rp.93,231,432. Net Profit is calculated in the period of the year during the economic life of 20 years, with an inflation rate of 3.5% based on the average inflation of the last 10 years in Indonesia, for details of cash inflows or net profit (Net Profit) are presented in table 13 below:

Table 13 Cash inflow or net profit of biodigester

Year	O&M (3.5% inflation)	Depreciation	Total Expenses	Income	Net Profit
1	IDR 15,200,000	IDR 8,670,000	IDR 23,870,000	IDR 93,231,432	IDR 69,361,432
2	IDR 15,732,000	IDR 8,670,000	IDR 24,402,000	IDR 93,231,432	IDR 68,829,432
3	IDR 16,282,620	IDR 8,670,000	IDR 24,952,620	IDR 93,231,432	IDR 68,278,812
4	IDR 16,852,512	IDR 8,670,000	IDR 25,522,512	IDR 93,231,432	IDR 67,708,920
5	IDR 17,442,350	IDR 8,670,000	IDR 26,112,350	IDR 93,231,432	IDR 67,119,082
6	IDR 18,052,832	IDR 8,670,000	IDR 26,722,832	IDR 93,231,432	IDR 66,508,600
7	IDR 18,684,681	IDR 8,670,000	IDR 27,354,681	IDR 93,231,432	IDR 65,876,751
8	IDR 19,338,645	IDR 8,670,000	IDR 28,008,645	IDR 93,231,432	IDR 65,222,787
9	IDR 20,015,497	IDR 8,670,000	IDR 28,685,497	IDR 93,231,432	IDR 64,545,935
10	IDR 20,716,040	IDR 8,670,000	IDR 29,386,040	IDR 93,231,432	IDR 63,845,392
11	IDR 21,441,101	IDR 8,670,000	IDR 30,111,101	IDR 93,231,432	IDR 63,120,331
12	IDR 22,191,540	IDR 8,670,000	IDR 30,861,540	IDR 93,231,432	IDR 62,369,892
13	IDR 22,968,244	IDR 8,670,000	IDR 31,638,244	IDR 93,231,432	IDR 61,593,188
14	IDR 23,772,132	IDR 8,670,000	IDR 32,442,132	IDR 93,231,432	IDR 60,789,300
15	IDR 24,604,157	IDR 8,670,000	IDR 33,274,157	IDR 93,231,432	IDR 59,957,275
16	IDR 25,465,302	IDR 8,670,000	IDR 34,135,302	IDR 93,231,432	IDR 59,096,130
17	IDR 26,356,588	IDR 8,670,000	IDR 35,026,588	IDR 93,231,432	IDR 58,204,844
18	IDR 27,279,068	IDR 8,670,000	IDR 35,949,068	IDR 93,231,432	IDR 57,282,364
19	IDR 28,233,836	IDR 8,670,000	IDR 36,903,836	IDR 93,231,432	IDR 56,327,596
20	IDR 29,222,020	IDR 8,670,000	IDR 37,892,020	IDR 93,231,432	IDR 55,339,412

4. Net Present Value (NPV) Biodigester

At this stage, from the data on cash inflows or net profit (Net Profit) for 20 years, the Net Present Value (NPV) is calculated, with the Bungan rate referring to Bank Indonesia in 2024 of 6%, the Net Present Value (NPV) can be calculated using the ratio (Fernández-Gonzalez, Grindlay, Serrano-Bernardo, Rodríguez-Rojas, & Zamorano, 2017), the details of the calculation and NPV value are presented below:

$$PV_{1,.} = \left(\frac{Rp69.361.432}{(1+6\%)^1}\right) = Rp65.435.313$$

$$NPV = Rp755.167.389 - Rp178.400.000 = Rp576.767.389$$

Tabel 14 Net present value biodigester

Year	Cash flow in/net profit	6,00%	Present Value

		Discount Factor	
1	IDR 69,361,432	1,060	IDR 65,435,313
2	IDR 68,829,432	1,124	IDR 61,257,949
3	IDR 68,278,812	1,191	IDR 57,328,207
4	IDR 67,708,920	1,262	IDR 53,631,807
5	IDR 67,119,082	1,338	IDR 50,155,283
6	IDR 66,508,600	1,419	IDR 46,885,939
7	IDR 65,876,751	1,504	IDR 43,811,802
8	IDR 65,222,787	1,594	IDR 40,921,584
9	IDR 64,545,935	1,689	IDR 38,204,640
10	IDR 63,845,392	1,791	IDR 35,650,934
11	IDR 63,120,331	1,898	IDR 33,251,003
12	IDR 62,369,892	2,012	IDR 30,995,926
13	IDR 61,593,188	2,133	IDR 28,877,290
14	IDR 60,789,300	2,261	IDR 26,887,166
15	IDR 59,957,275	2,397	IDR 25,018,076
16	IDR 59,096,130	2,540	IDR 23,262,972
17	IDR 58,204,844	2,693	IDR 21,615,208
18	IDR 57,282,364	2,854	IDR 20,068,520
19	IDR 56,327,596	3,026	IDR 18,617,003
20	IDR 55,339,412	3,207	IDR 17,255,090
	Total		Rp739.131.712
	Salvage Value		IDR 16,035,677
	Total Present Value		Rp755.167.389
	Investment		Rp178.400.000
	NPV		Rp576.767.389

The total value of future cash inflows or net profit (Net Profit) in the present value is IDR 739,131,712, the salvage value in the 20th year is equivalent to IDR 16,035,677 in 2024, the total revenue obtained in the 20th year is equivalent to IDR 755,167,389 this year, the total revenue minus the initial investment cost, the Net Present Value (NPV) is obtained of IDR 576,767,389. This nili is positively greater than the initial investment cost so it can be said that this project worthy of running.

5. Internal Rate of Return (IRR) Biodigester

To calculate the value of the IRR can use equation (Haryanto, Okfrianas, & Rahmawati, 2019), Although the IRR does not have a simple formula like NPV, the calculation is obtained by using the trial and error method or financial software such as Excel, the IRR shows the discount rate at which the NPV of all future cash flows of the project is equal to zero.

When NPV is 0, the discount rate used is equal to the Internal Rate of Return (IRR) of the project. The investment generates enough cash flow to cover all initial costs and meet the expected rate of return, but does not generate a surplus profit, which is expected when the IRR value is greater than the rate of return on investment then the project is said to be feasible, the IRR obtained for biodigester technology is 38% of the project is said to be feasible.

Tabel 15 Internal Rate of Return biodigester

IRR					
Year	Cash flow in/ Benefit	Year	Cash flow in/ Benefit	Year	Cash flow in/ Benefit
0	-Rp178.400.000	9	IDR 64,545,935	18	IDR 57,282,364
1	IDR 69,361,432	10	IDR 63,845,392	19	IDR 56,327,596
2	IDR 68,829,432	11	IDR 63,120,331	20	IDR 55,339,412
3	IDR 68,278,812	12	IDR 62,369,892	IRR	38%
4	IDR 67,708,920	13	IDR 61,593,188		
5	IDR 67,119,082	14	IDR 60,789,300		
6	IDR 66,508,600	15	IDR 59,957,275		
7	IDR 65,876,751	16	IDR 59,096,130		

8	IDR 65,222,787	17	IDR 58,204,844

6. Payback Period (PBP) Biodigester

To find out how long the initial investment cost will be returned, it can be seen from the accumulated cash inflow or net profit, based on the cash inflow in table 15 PBP biodigester technology investment is obtained in the 3rd year, and gets a profit of IDR 28,069,676, for the details of PBP are presented in table 16 below:

Tabel 16 Payback period biodigester

Payback Period				
Period	0 Years	1 Year	2 Years	3 Years
Net Profit	-Rp178.400.000	IDR 69,361,432	IDR 68,829,432	IDR 68,278,812
Accumulation	-Rp178.400.000	-Rp109.038.568	-Rp40.209.136	IDR 28,069,676

7. Benefit Cost Ratio (BCR) Biodigester

To find out the ratio ratio between income (benefit) and expenditure (cost) can be calculated using equation (Kumar & Samadder, 2017) with a discount interest rate of 6% based on Bank Indonesia data, the BCR biodigetser ratio is 2.24 greater than 1 so that the benefits of the investment to be incurred are greater than the costs incurred, so that the investment plan can be accepted or declared feasible, For details of the calculation and BCR ratio, it is presented in table 17 below:

$$PVBt_{1,.} = \left(\frac{Rp69.361.432}{(1+6\%)^1}\right) = Rp65.435.313$$

$$PVCt_{1,.} = \left(\frac{Rp23.870.000}{(1+6\%)^1}\right) = Rp22.518.868$$

$$BCR = \frac{Rp739.131.712}{\text{Rp}330.225.468} = 2.24$$

Tabel 17 Benefit cost ratio biodigester

BCR						
Year	Benefit Year	6,00% Discount Factor	Peresent Value	Cost Year	6,00% Discount Factor	Peresent Value
1	IDR 69,361,432	1,06	IDR 65,435,313	IDR 23,870,000	1,06	IDR 22,518,868
2	IDR 68,829,432	1,12	IDR 61,257,949	IDR 24,402,000	1,12	IDR 21,717,693
3	IDR 68,278,812	1,19	IDR 57,328,207	IDR 24,952,620	1,19	IDR 20,950,701
4	IDR 67,708,920	1,26	IDR 53,631,807	IDR 25,522,512	1,26	IDR 20,216,220
5	IDR 67,119,082	1,34	IDR 50,155,283	IDR 26,112,350	1,34	IDR 19,512,667
6	IDR 66,508,600	1,42	IDR 46,885,939	IDR 26,722,832	1,42	IDR 18,838,542
7	IDR 65,876,751	1,50	IDR 43,811,802	IDR 27,354,681	1,50	IDR 18,192,425
8	IDR 65,222,787	1,59	IDR 40,921,584	IDR 28,008,645	1,59	IDR 17,572,970
9	IDR 64,545,935	1,69	IDR 38,204,640	IDR 28,685,497	1,69	IDR 16,978,902
10	IDR 63,845,392	1,79	IDR 35,650,934	IDR 29,386,040	1,79	IDR 16,409,011
11	IDR 63,120,331	1,90	IDR 33,251,003	IDR 30,111,101	1,90	IDR 15,862,152
12	IDR 62,369,892	2,01	IDR 30,995,926	IDR 30,861,540	2,01	IDR 15,337,240
13	IDR 61,593,188	2,13	IDR 28,877,290	IDR 31,638,244	2,13	IDR 14,833,243
14	IDR 60,789,300	2,26	IDR 26,887,166	IDR 32,442,132	2,26	IDR 14,349,186
15	IDR 59,957,275	2,40	IDR 25,018,076	IDR 33,274,157	2,40	IDR 13,884,143
16	IDR 59,096,130	2,54	IDR 23,262,972	IDR 34,135,302	2,54	IDR 13,437,235
17	IDR 58,204,844	2,69	IDR 21,615,208	IDR 35,026,588	2,69	IDR 13,007,628
18	IDR 57,282,364	2,85	IDR 20,068,520	IDR 35,949,068	2,85	IDR 12,594,533
19	IDR 56,327,596	3,03	IDR 18,617,003	IDR 36,903,836	3,03	IDR 12,197,198
20	IDR 55,339,412	3,21	IDR 17,255,090	IDR 37,892,020	3,21	IDR 11,814,911
Total Present Value of Benefit			IDR 739,131,712	Total Present Value of Cost		IDR 330,225,468
BCR			2,24			

Specification of Pyrolysis

Based on the results of AHP-Fuzzy TOPSIS pyrolysis received the second priority ranking, pyrolysis is used to process residual waste, thereby minimizing the disposal of waste to the Cipayung landfill, so that there is a savings in the payment of waste disposal levy to the landfill, the pyrolysis technology used this time is locally made AWS pyrolysis by PT. Indopower International and has pocketed environmentally friendly exhaust smoke quality standards from the Ministry of Environment, in AWS pyrolysis the output of the product produced from combustion is fly ash, this pyrolysis uses a circulating fluidized bed type reactor where the initial heat source is obtained from the combustion of wood-type dry biomass assisted by a diesel burner until the tamper reaches 300o C, After that, the residual waste can be put into the reactor, the temperature of the combustion chamber can reach 400-900oC, the heat that occurs is circulated to maintain the temperature, there are 2 combustion chamber chambers to perfect the exhaust gas, the exhaust gas through the Cyclone separator separates the particles from the exhaust gas flow, the separate particles are Fly Ash, for the heat generated from the reactor can be transferred to heat the water or dry the wet residual waste. This pyrolysis has energy costs or operating costs that are economical because it only requires fuel at the beginning to reach the initial temperature and saves water because of using a cyclone separator. This pyrolysis operates a batching system with a capacity of 10 TPD 8 working hours, within a year 365 days this tool is able to process residual waste as much as 3,650,000 kg/year, in one system this tool is already a full unit1 unit of IPI AWS 50, 1 unit of Hopper & Bag Opener, 1 unit of Conveyor to Automatic Sorting Machine, 1 unit of Automatic Sorting Machine, 1 unit of Pyrolysis Machine Conveyor, 1 unit of ETS-3000 and 1 set of Control & Instrument), the residue produced from the combustion process of 5% for details can be seen in table 18 below:

Table 18 AWS 10 TPD Pyrolysis Specification

Type	AWS 10 TPD
Full Unit	1 unit of IPI AWS 50, 1 *unit of Hopper & Bag Opener*, 1 unit of Conveyor to Automatic Sorting Machine, 1 unit of Automatic Sorting Machine, 1 unit of Conveyor to Pyrolysis Machine, 1 unit of ETS-3000 and 1 set of Control & Instrument
Capacity	10 TPD
Heavy	10 Tons
Emission	Meet quality standards
Output	Ash, Hot Water,Hot Air
Price	Rp. 1.206.000.000
Temperature	400-900°C
Residue	5%
Chamber	2 combustion chambers
Filter gas	*Cyclone separator*
Warranty	1 year

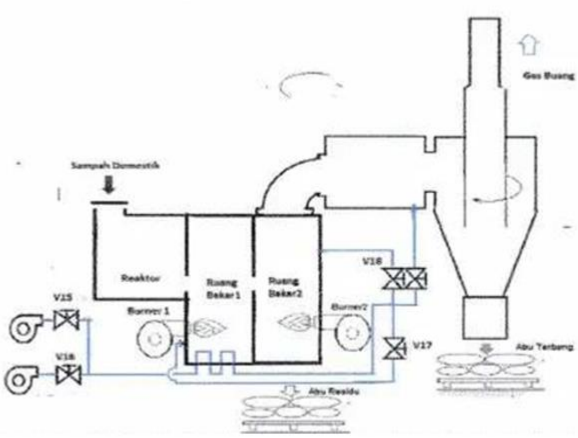

Figure 3. AWS Schematic Pyrolysis

Figure 4. IPI AWS Pyrolysis 10 TPD

Techno Economy Pyroli

At this stage, the IPI AWS 10 TPD Pyrolysis is calculated for its economic value, starting from the initial investment cost, Net Present Value (NPV), Internal Rate of Return (IRR), Pay Back Period (PBP), and Benefit Cost Ratio (BCR).

1. Cost Aspects of Pyrolysis

The price of IPI AWS 10 TPD pyrolysis technology is obtained from the LKPP catalog, the selection of the model is based on the existing waste generation and the assumption of the annual growth of residual waste generation of 10% to the next 10 years, so that the ability of priolisis technology can process the generation of residual waste for up to 10 years. The AWS 10 TPD pyrolysis model is capable of processing a maximum of 3,650,000 kg of residual waste per year, there are installation costs and training costs that are assumed, for the details of the total initial investment value of AWS 10 TPD pyrolysis technology is presented in table 19 below:

Table 19 Pyrolysis investment costs

Kind	Price/Item	Qty	Total/Qty	Information
Full Sistem Pirolisis AWS 10 TPD	IDR 1,206,000,000	1	IDR 1,206,000,000	PT. Indopower International
Instalasi	IDR 10,000,000	1	IDR 10,000,000	
Training	IDR 2,000,000	1	IDR 2,000,000	
Land	IDR 0		IDR 0.00	land owned by UI
Building	IDR 0		IDR 0.00	UI building
Unexpected	IDR 30,000,000	1	IDR 30,000,000,00	
TOTAL			IDR 1,248,000,000	

From the table above, it can be seen that the total value of the initial investment cost is IDR 1,248,000,000, the provision of land and buildings provided by the University of Indonesia is already available. Of course, in operating AWS 10 TPD Pyrolysis, operational and operational costs (O&M) are required, for operational costs and maintenance per year are certainly higher than biodigester technology, for assuming detailed operational and operational costs are presented in table 20 below:

Table 20 Operational costs & pyrolysis treatment

Kind	Qty	Interval	Price/Item	Price/Year	Information
Maintenance	12	1 Month	IDR 300,000	IDR 3,600,000	Combustion chamber cleaning
FUEL	30	Liters/1 month	IDR 14,000	IDR 5,040,000	for Starting Combustion
Electricity	12	1 month	IDR	IDR 54,000,000	

			4,500,000		
Workforce	2	-	IDR 0	IDR 0	3rd party UI
APD (masker respirator)	2	Pcs/6 months	IDR 400,000	IDR 800,000	Masks Respirator
Unexpected	1	1 month	IDR 200,000	IDR 2,400,000	
Total/Year				IDR 65,840,000	

2. Aspects of Depreciation and Salvage Value of Pyrolysis

At this stage, the depreciation value of the AWS 10 TPD Pyrolysis technology is calculated, distinguish the initial investment value and the economic life of the technology itself, the economic life of this pyrolysis technology is 10 years, the depreciation method used is the straight line method, and it is assumed that the salvage value is Rp.45,000,000 where at the end of the life of the biodigester technology system there is still a residual value obtained from the sale of scrap metal materials, from this assumption, the annual depreciation of this Pyrolysis technology is obtained of Rp120,300,000, For details of the depreciation value can be seen in table 21, depreciation can be calculated using Persaman following the details of depreciation and residual value below:

Table 21 Depreciation & salvage value of pyrolysis

Kind	Investment Price	Residual Value (SV)	Economic Age (Years)	Depreciation/Year
Pirolisis AWS	IDR 1,248,000,000	IDR 45,000,000	10	IDR 120,300,000

3. Aspects of Pyrolysis Cash Flow

To find out the cash inflow or net profit (Net Profit) that we receive, it is necessary to calculate between the cost of expenditure (O&M) and the cost of income, where the cost of income is generated from the levy fee that should be paid if the payment is made to the landfill, for the levy rate of Rp.100,000 per m3 of waste, the conversion value of SNI 3242-2008 1 cubic meter of garbage is equal to 200 kg. Net Profit is calculated in the Year period during the economic life period of 10 years, with an inflation rate of 3.5%, and an increase in residual waste generation of 10% per year for the details of cash inflows or net profit (Net Profit) presented in table 22 below:

Table 22 Pyrolysis cash inflows or net profit

Era	Year 1	Year 2	Year 3	Year 4	Year 5
Residual Weight (kg)	959.743	1.055.717	1.161.289	1.277.418	1.405.160
Volume (m3)	4.799	5.279	5.806	6.387	7.026
O & M	IDR 65,840,000	IDR 68,144,400	IDR 70,529,454	IDR 72,997,985	IDR 75,552,914
Depreciation	Rp120.300.000	Rp120.300.000	Rp120.300.000	Rp120.300.000	Rp120.300.000
Total Expenditure	Rp186.140.000	Rp188.444.400	Rp190.829.454	Rp193.297.985	Rp195.852.914
Levy Fee	Rp479.871.500	Rp527.858.650	Rp580.644.515	Rp638.708.967	Rp702.579.863
Net Profit	Rp293.731.500	Rp339.414.250	Rp389.815.061	Rp445.410.982	Rp506.726.949
Period	Year 6	7 years	Year 8	Year 9	Year 10
Residual Weight (kg)	1.545.676	1.700.243	1.870.268	2.057.294	2.263.024
Volume (m3)	7.728	8.501	9.351	10.286	11.315
O & M	IDR 78,197,266	IDR 80,934,171	IDR 83,766,867	IDR 86,698,707	IDR 89,733,162
Depreciation	Rp120.300.000	Rp120.300.000	Rp120.300.000	Rp120.300.000	Rp120.300.000
Total Expenditure	Rp198.497.266	Rp201.234.171	Rp204.066.867	Rp206.998.707	Rp210.033.162
Levy Fee	Rp772.837.849	Rp850.121.634	Rp935.133.798	Rp1.028.647.178	Rp1.131.511.895
Net Profit	Rp574.340.583	Rp648.887.464	Rp731.066.931	Rp821.648.471	Rp921.478.734

4. Net Present Value (NPV) Pirolisis

At this stage, from the data on cash inflows or net profit (Net Profit) for 10 years, the Net Present Value (NPV) is calculated, with the Bungan rate referring to Bank Indonesia in 2024 of 6%, the Net Present Value (NPV) obtained is Rp2,766,526,609, this shows that the investment is feasible, NPV can be calculated using the ratio, the NPV value is presented in table 23 below:

Tabel 23 Net present value pirolisis

Year	Cash flow in/net profit	6,00% Discount Factor	Present Value
1	Rp293.731.500	1,060	Rp277.105.189
2	Rp339.414.250	1,124	Rp302.077.474
3	Rp389.815.061	1,191	Rp327.296.242
4	Rp445.410.982	1,262	Rp352.807.216
5	Rp506.726.949	1,338	Rp378.655.854
6	Rp574.340.583	1,419	Rp404.887.448
7	Rp648.887.464	1,504	Rp431.547.224
8	Rp731.066.931	1,594	Rp458.680.437
9	Rp821.648.471	1,689	Rp486.332.467
10	Rp921.478.734	1,791	Rp514.548.912
Total			Rp3.933.938.463
Salvage Value			IDR 80,588,146
Total Present Value			Rp4.014.526.609
Investment			Rp1.248.000.000
NPV			Rp2.766.526.609

5. Internal Rate of Return (IRR) Pirolisis

Although IRR does not have a simple formula like NPV, the calculation is obtained using the trial and error method or financial software such as Excel. When the IRR value is greater than the rate of return on investment, the project is said to be feasible, the IRR obtained for pyrolysis technology is 32% of the project is said to be feasible, the IRR data is presented in table 24 below:

Tabel 24 Internal Rate of Return

Year	Cash flow in/ Benefit	Year	Cash flow in/ Benefit
0	-Rp1.248.000.000	6	Rp574.340.583
1	Rp293.731.500	7	Rp648.887.464
2	Rp339.414.250	8	Rp731.066.931
3	Rp389.815.061	9	Rp821.648.471
4	Rp445.410.982	10	Rp921.478.734
5	Rp506.726.949	IRR	32%

6. Pay Back Period (PBP) Pirolisis

To find out how long the initial investment cost will be returned, it can be seen from the accumulated cash inflow or net profit, based on the cash inflow in table 4.28 PBP of biodigester technology investment obtained in the 4th year, and obtained a profit of IDR 220,371,793, for the details of PBP presented in table 25 below:

Table 25 Payback period of pyrolysis

Period	Net Profit	Accumulation
Year 0	-Rp1.248.000.000	-Rp1.248.000.000
Year 1	Rp293.731.500	-Rp954.268.500
Year 2	Rp339.414.250	-Rp614.854.250
Year 3	Rp389.815.061	-Rp225.039.189
Year 4	Rp445.410.982	Rp220.371.793

7. Benefit Cost Ratio (BCR) Pirolisis

To find out the ratio between income (benefit) and expenses (cost) with a discount interest rate of 6%, the BCR Pyrolysis ratio is 2.72 greater than 1 so that the benefits of the investment to be incurred are greater than the costs incurred, so that the investment plan can be accepted or declared feasible, for the details of the BCR ratio presented in table 26 below:

Tabel 26 Benefit cost ratio pirolisis

Year	Benefit/Year	6,00%	Perensent Value	Cost/Year	6,00%	Peresent Value
		Discount Factor			Discount Factor	
1	Rp293.731.500	1,060	Rp277.105.189	Rp186.140.000	1,060	Rp175.603.774
2	Rp339.414.250	1,124	Rp302.077.474	Rp188.444.400	1,124	Rp167.714.845
3	Rp389.815.061	1,191	Rp327.296.242	Rp190.829.454	1,191	Rp160.224.089
4	Rp445.410.982	1,262	Rp352.807.216	Rp193.297.985	1,262	Rp153.110.109
5	Rp506.726.949	1,338	Rp378.655.854	Rp195.852.914	1,338	Rp146.352.691
6	Rp574.340.583	1,419	Rp404.887.448	Rp198.497.266	1,419	Rp139.932.740
7	Rp648.887.464	1,504	Rp431.547.224	Rp201.234.171	1,504	Rp133.832.217
8	Rp731.066.931	1,594	Rp458.680.437	Rp204.066.867	1,594	Rp128.034.077
9	Rp821.648.471	1,689	Rp486.332.467	Rp206.998.707	1,689	Rp122.522.217
10	Rp921.478.734	1,791	Rp514.548.912	Rp210.033.162	1,791	Rp117.281.420
	Total Present Value of Benefit		Rp3.933.938.463	Total Present Value of Cost		Rp1.444.608.179
	BCR			3,72		

CONCLUSION

The conclusion obtained is that from the calculation in the AHP method, the highest ranking weight priority is obtained by the environmental criteria ranked 1 with a weight of 0.532, technical ranking 2 with a weight of 0.225, economic ranking 3 with a weight of 0.142, and social ranking 4 with a weight of 0.101 where the highest subcriteria for emissions ranking 1 with a weight of 0.238, ranking 2 potential pollutants with a weight of 0.206, efficiency conversion ranking 3 with a weight of 0.140 and so on according to the AHP ranking priority weight table, This shows that the focus of technology selection is based on environmentally friendly technology. From the calculation in the AHP method, the highest ranking weight priority is obtained by the environmental criteria ranked 1st with a weight of 0.532, technical ranking 2nd with a weight of 0.225, economic ranking 3rd with a weight of 0.142, and social ranking 4th with a weight of 0.101 where the highest subcriteria for emissions ranked 1st with a weight of 0.238, ranking 2nd with a potential pollutant with a weight of 0.206, efficiency conversion with a weight of 0.140 and so on according to the AHP ranking priority weight table, This shows that the focus of technology selection is based on environmentally friendly technology. For techno, eco-technology, biodigester technology is said to be feasible to be applied with a positive NPV value of IDR 576,767,389 greater than the investment value, IRR 38% greater than the rate of return, BCR 2.24 greater than 1, and a quick return on investment in the 3rd year and earning a profit of IDR 28,069,676. For pyrolysis technology, it is said to be feasible to be applied with a positive NPV value of IDR 2,766,526,609 greater than the investment value, IRR 32% greater than the rate of return, BCR 2.72 greater than 1, and a quick return on investment in the 4th year and get savings of IDR 220,371,793, in this case pyrolysis can substitute the residual waste levy so that savings are obtained.

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