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Analysis of Palm Biomass Potential for Renewable Energy Sources

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ABSTRACT

Heaps of palm oil waste resulting from the rapid development of PKS, causing the risk of environmental pollution, decreased productivity and income of the people living in the factory area. in order to achieve the research objective, namely to find out the opportunities for palm biomass as a renewable energy source using the Composite Performance Index method and later be able to make a decision. Based on the implementation of the research conducted, it was found that only one sustainable biomass was palm shell with a value of 437.5, POME, a value of 425.4 fibers, a value of 367.17 and empty fruit bunches with a value of 343.82.

Keywords: *Biomassa, Composite Performance Index, Palm Oil Waste*

Introduction

In recent years, global environmental issues have permeated many sectors, including the palm oil industry. Controversy has arisen due to widespread allegations that palm oil mills are responsible for creating environmental problems due to the large volumes of contaminated waste discharged into surrounding ecosystems. To maintain its competitiveness, the palm oil industry sector must strive to meet quality standards and uphold environmental preservation through sustainable development approaches and the adoption of environmentally friendly technologies. Rapid advancements in the palm oil industry have a significant impact on the surrounding environmental conditions. Waste generated by the palm oil processing sector is a by-product that arises from the stages of palm oil management and has a direct impact on the environment if not managed properly.

The impact of palm oil mill waste on natural resources and settlements is then polluted by residents' well infiltration water, air pollution due to palm oil mill pollution and noise pollution, so it is necessary to utilize technology in managing waste by converting waste into renewable energy sources [1]. Bioenergy is a source of energy produced through biomass processes [2]. Biomass is among the renewable and environmentally sound resources that can overcome greenhouse gas emissions. Biomass comes from plants and animals as well as the side materials themselves such as garden waste, palm oil waste, animal manure and so on [3]. Energy derived from biomass is obtained from waste materials. This waste is generated from agricultural activities, plantations, and forest harvesting, then processed to become a renewable energy source [4]. Waste is the residual result of various productivity processes, both on a company scale and in the local environment. This waste is referred to as remnants, which at some times and places, especially in the environment, are undesirable because they lack economic value [5].

Tankos (empty bunches), fibers, and shells are types of solid waste generated by palm oil processing plants. Meanwhile, POME waste comes from 3 main sources, namely condensate water from the sterilization process, sludge and dirt, and also water used to wash hydrocyclones [6]. to handle these problems, a structure called decision support (SPK) is important [7], where a decision support system is a framework designed to provide support in the decision-making process when facing complex situations [8]. Decision support systems only present different decision options, but the final determination still depends on the decision made by the decision maker. Its function is not to replace the role of the decision maker, but to perform the role of an instrument of support and support in the decision-making process [9]. Decision support systems that rely on the CPI method work by selecting the optimal choice after evaluating the results of relevant criteria. This process involves using predetermined weights for each criterion to determine the best alternative [10]. The goal is to provide a framework, gather information and offer more efficient recommendations [11].

Research method

Below are the steps of the research carried out can be observed in Figure 1 below.

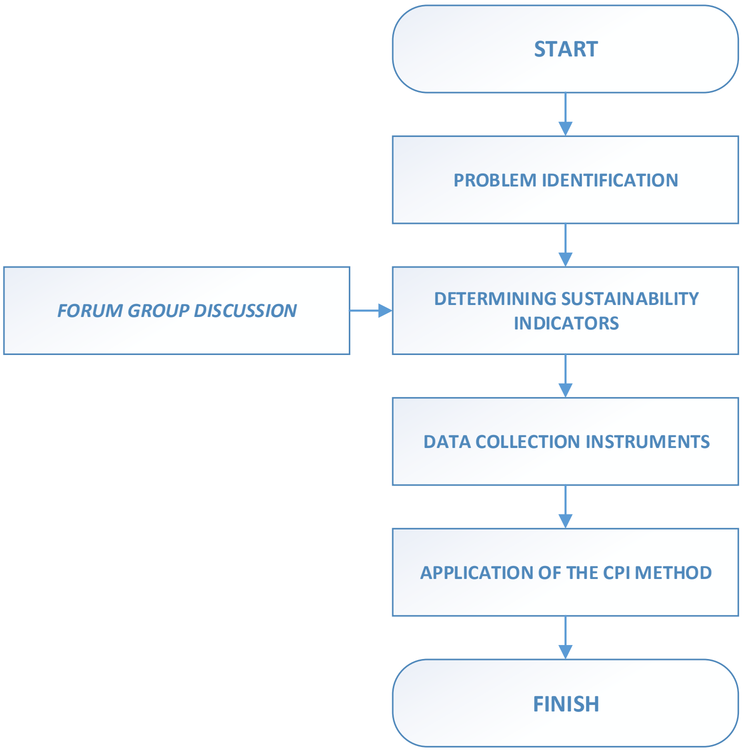

Figure 1: Research Stages

Figure 1 describes some of the research steps that were carried out as follows:

a. Problem identification, which is an introduction to the most common problems encountered when determining palm biomass potential based on sustainability indicators.
b. Determining sustainability indicators, namely determining indicators through FGDs in this case involving experts who are directly related to this research
c. Data collection instruments, namely making a questionnaire which is then distributed to related experts
d. Application of the CPI method, which is to obtain results that will determine decision making

The method used in this study is a composite performance index (CPI) where this method is a useful tool for evaluating or ranking various alternatives (i) based on a number of different criteria (j). This can act as a basis or reference that is taken into account in the process of making a decision in the acceptance of chefs by weighting each prospective chef who registers [11].

The final output of this CPI is to display the ranking of individuals who are eligible to receive support from the government's home rehabilitation program. This decision-making system contributes to identifying residents who are eligible for home improvement assistance through the ranking data generated by the system after processing. With this system, the village will be assisted in determining more accurately those who really need home repairs, by relying on the ranking results formed in the system [12]. Before using the CPI method, it is necessary to determine several criteria based on the Indonesian bioenergy sustainability indicator (IBSI). The following is the sustainability of palm oil bioenergy in Indonesia can be observed in table 1 below [13].

Table 1. Sustainability of Oil Palm Bioenergy in Indonesia

Sustainability Criteria	indicators
Environment	Life cycle of GHG emissions Waste management and production cleanup (soil, air, water and quality and efficiency)
Social	Impact of changes in income Jobs in the bioenergy sector Bioenergy used to expand access to modern productivity

Economy	productivity Net energy balance Gross value added Energy diversity Infrastructure and logistics for bioenergy distribution

The following are the stages of the procedure in applying the composite performance index method as follows [14].

1. Identifying positive and negative trend criteria
   The first step is to identify the criteria applied that indicate a positive or negative trend direction. If the trend is considered positive (+) the higher the value, the better, while if the trend is considered negative (-) the lower the value, the better.
2. Changes in positive and negative trend values
   In criteria that show a positive trend, if the minimum number here acts as a divider in the calculation for the value of each criterion, it will then be multiplied by one hundred. However, when there are criteria that show a negative trend, the minimum number is divided by the other values in each criterion, which will then be multiplied by one hundred.
3. Calculation of alternative index values
   Where the criteria value is multiplied by the weight value
4. Combined index value calculation
   This value is generated from the sum of alternative indices
   After the procedure steps are explained, the composite index formula is as follows:

$$A(i+1.j) = (x(i+1.j) / xij(min)) \times 100 \quad (1)$$

$$A(i+1.j) = (xij\ (min) / x(i+1.j\ ) \times 100 \quad (2)$$

$$Iij = Aij \times Pj \quad (3)$$

$$Ii = \sum_{j=1}^{n} Iij \quad (4)$$

Description:
Aij : the nth alternative number at the nth criterion value
Xij(min) : nth alternative number at the nth minimum initial criterion value
A(i=1.j) : n+1th alternative number at the nth criterion value
Pj : weight of each criterion
Iij : value of alternative index
Ii : value of the combined index

Results and discussion

The following are the results and analysis using the CPI method.

Data identification

In determining rankings, the data that you want to process or also called alternative data is shown in table 2 alternative data.

Table 2. Alternative Data

Code	Alternative	type of waste	Description
A1	Shell	Solid	The remnants obtained from the palm oil extraction process have not been fully utilized optimally.
A2	Fibers	Solid	Waste from palm fruit juice in the form of stringy fibers
A3	Empty fruit bunches	Solid	by-product of oil palm fruit processing.
A4	POME	Liquid	Liquid waste can be utilized to produce

		energy by capturing methane gas and converting biogas into electrical energy.

Determination of criteria, trends, and weights

To complete the value calculation using the CPI method, first determine the criteria which can be seen in table 1. The sustainability of palm oil bioenergy in Indonesia, determining the positive trends and negative trends of each criterion and each criterion is given a weight, where the company determines the weight value itself. Therefore, this weight value contains an objective assessment (facts and data in the field). Table 3. can be seen below as follows.

Table 3. Determination of Criteria, Trends and Weights

Code	Criteria	Description	Trend	Weight(%)
L1	GHG emission reduction	Lowering the greenhouse effect	Negative	8
L2	Water use efficiency	Clean water usage	Positive	7
L3	Air quality	Existing emission air quality at the mill	Negative	5
E1	Infrastructure	Building and road conditions	Positive	5
E2	Energy diversification	Utilization of energy sources for energy supply	Positive	15
E3	Productivity	Production for core and crude oil	Positive	8
E4	Net energy ratio	Energy balance for bioenergy development	Positive	15
E5	Gross value added	Parameterized values of production values and costs incurred	Positive	5
S1	Labor force	Labor absorption	Positive	7
S2	Income	Wages of workers	Positive	10
S3	Bioenergy use	Source of bioenergy for electricity and boilers	Positive	15

Scaling and grade conversion

The next step is to determine the scale and value conversion for each criterion as follows.

Table 4. Scale Determination and Value Conversion

Criteria Code	Trend	Scale range	Value conversion
L1	Negative	High emission	1
		Medium emission	2
		Less emission	3
		No emission	4
L2	Positive	None	1
		Little	2
		Moderately abundant	3
		Very abundant	4
L3	Negative	Very polluted	1
		Pollution	2
		Less pollution	3
		No pollution	4
E1	Positive	Collapsed state	1
		Cracked state	2
		Pretty good	3
		Good condition	4
E2	Positive	Not useful	1
		Less useful	2
		Quite useful	3
		Very useful	4
E3	Positive	Not productive	1
		Less productive	2
		Moderately productive	3
		Very productive	4

E4	Positive	Unbalanced	1
		Less balanced	2
		Fairly balanced	3
		Very balanced	4
E5	Positive	Not balanced	1
		Less balanced	2
		Fairly balanced	3
		Very balanced	4
S1	Positive	None	1
		Less crowded	2
		Quite crowded	3
		Very crowded	4
S2	Positive	Not suitable	1
		Less suitable	2
		Quite suitable	3
		Very suitable	4
S3	Positive	Not needed	1
		Less required	2
		Quite needed	3
		Very much needed	4

Grade conversion result

Then from the existing alternatives, the evaluation is carried out on predetermined parameters. The assessment of the criteria is taken from the results of 3 experts, namely Rudi Siholman (X1), Jumanto (X2) and Fitra Lestari Nohirza (X3) which are converted and directly determine the minimum value of each criterion for each respondent as shown in tables 5, 6 and 7. To make it easier to distinguish between positive and negative trends, red (positive trends) and blue (negative trends) are given.

Table 5. X1 Respondents

Code	Alternative	CRITERIA										
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3
A1	Shell	1	1	1	3	4	1	4	3	3	3	4
A2	Fibers	1	1	1	3	4	1	3	3	3	3	3
A3	Tankos	4	1	4	3	1	4	1	3	3	3	1
A4	POME	1	3	2	3	3	2	2	3	3	3	2
Minimum value		**1**	**1**	**1**	**3**	**1**	**1**	**1**	**3**	**3**	**3**	**1**

Table 6. X2 Respondents

Code	Alternative	CRITERIA										
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3
A1	Shell	2	3	2	3	3	3	3	3	4	3	3
A2	Fibers	2	2	3	3	2	3	2	2	3	2	3
A3	Tankos	1	2	3	3	3	3	1	1	4	2	3
A4	POME	2	4	1	3	2	3	3	2	2	3	3
Minimum Value		**1**	**2**	**1**	**3**	**2**	**3**	**1**	**1**	**2**	**2**	**3**

Table 7. X3 Respondents

Code	Alternative	CRITERIA										
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3
A1	Shell	3	3	3	2	3	2	2	3	3	3	3
A2	Fibers	3	3	3	2	3	2	2	3	3	3	3
A3	Tankos	3	3	3	2	4	2	2	3	3	3	3
A4	POME	4	3	3	2	4	2	3	3	3	3	3
Minimum value		**3**	**3**	**3**	**2**	**3**	**2**	**2**	**3**	**3**	**3**	**3**

Positive and negative trend calculation

After the value for each alternative is converted, calculations are then carried out to assist researchers in processing data, an application software called Microsoft Excel is needed. For criteria L1 and L3 are negative trends while criteria L2, E1, E2, E3, E4, E5, S1, S2 and S3 are positive trends. Below is the process of positive and negative trends from respondent X1 using Excel software.

CALCULATION OF POSITIVE AND NEGATIVE TRENDS

Code	Alternative	CRITERIA										
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3
A1	Shell	1	1	1	3	4	1	4	3	3	3	4
A2	Fiber	1	1	1	3	4	1	3	3	3	3	3
A3	Empty fruit bunches	4	1	4	3	1	4	1	3	3	3	1
A4	POME	1	3	2	3	3	2	2	3	3	3	2
Minimum Value		1	1	1	3	1	1	1	3	3	3	1
		(1/1*100)	(1/1*100)	(1/1*100)	(3/3*100)	(4/1*100)	(1/1*100)	(4/1*100)	(3/3*100)	(3/3*100)	(3/3*100)	(4/1*100)
		(1/1*100)	(1/1*100)	(1/1*100)	(3/3*100)	(4/1*100)	(1/1*100)	(3/1*100)	(3/3*100)	(3/3*100)	(3/3*100)	(3/1*100)
		(1/4*100)	(1/1*100)	(1/4*100)	(3/3*100)	(1/1*100)	(4/1*100)	(1/1*100)	(3/3*100)	(3/3*100)	(3/3*100)	(1/1*100)
		(1/1*100)	(3/1*100)	(1/2*100)	(3/3*100)	(3/1*100)	(2/1*100)	(2/1*100)	(3/3*100)	(3/3*100)	(3/3*100)	(2/1*100)

Figure 2. Calculation of Positive and Negative Trends from Respondent X1

In accordance with the results of the above calculations, the output of the positive trends and negative trends of X1, X2 and X3 are presented in the form of table 8 for X1, table 9. For X2 and table.10 for X3 as follows.

Table 8. Output of Positive and Negative Trend Values of X1

Code	Alternative	Crtiteria										
		L1	**L2**	**L3**	**E1**	**E2**	**E3**	**E4**	**E5**	**S1**	**S2**	**S3**
A1	Shell	100	100	100	100	400	100	400	100	100	100	400
A2	Fiber	100	100	100	100	400	100	300	100	100	100	300
A3	Empty fruit bunches	25	100	25	100	100	400	100	100	100	100	100
A4	POME	100	300	50	100	300	200	200	100	100	100	200

Table 9. Output of Positive and Negative Trend Values of X2

Code	Alternative	Crtiteria										
		L1	**L2**	**L3**	**E1**	**E2**	**E3**	**E4**	**E5**	**S1**	**S2**	**S3**
A1	Shell	50	150	50	100	150	100	300	300	200	150	100
A2	Fiber	50	100	33,3	100	100	100	200	200	150	100	100
A3	Empty fruit bunches	100	100	33,3	100	150	100	100	100	200	100	100
A4	POME	50	200	100	100	100	100	300	200	100	150	100

Table 10. Output of Positive and Negative Trend Values of X3

Code	Alternative	Crtiteria										
		L1	**L2**	**L3**	**E1**	**E2**	**E3**	**E4**	**E5**	**S1**	**S2**	**S3**
A1	Shell	100	100	100	100	100	100	100	100	100	100	100
A2	Fiber	100	100	100	100	100	100	100	100	100	100	100
A3	Empty fruit bunches	100	100	100	100	133,3	100	150	100	100	100	100
A4	POME	75	100	100	100	133,3	100	100	100	100	100	100

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Calculation of alternative index values

Where the criterion value is multiplied by the weight value. The following is the process of calculating the alternative index using formula (3) taken for example from respondent X1 is as follows

CALCULATION OF ALTERNATIVE INDEX VALUES

Code	Alternative	CRITERIA										
		L1 (-)	L2 (+)	L3 (-)	E1 (+)	E2 (+)	E3 (+)	E4 (+)	E5 (+)	S1 (+)	S2 (+)	S3 (+)
A1	Shell	100	100	100	100	400	100	400	100	100	100	400
A2	Fiber	100	100	100	100	400	100	300	100	100	100	300
A3	Empty fruit bunches	25	100	25	100	100	400	100	100	100	100	100
A4	POME	100	300	50	100	300	200	200	100	100	100	200
		(100*8%)	(100*7%)	(100*5%)	(100*5%)	(400*15%)	(100*8%)	(400*15%)	(100*5%)	(100*7%)	(100*10%)	(400*15%)
		(100*8%)	(100*7%)	(100*5%)	(100*5%)	(400*15%)	(100*8%)	(300*15%)	(100*5%)	(100*7%)	(100*10%)	(300*15%)
		(25*8%)	(100*7%)	(25*5%)	(100*5%)	(100*15%)	(400*8%)	(100*15%)	(100*5%)	(100*7%)	(100*10%)	(100*15%)
		(100*8%)	(300*7%)	(50*5%)	(100*5%)	(300*15%)	(200*8%)	(200*15%)	(100*5%)	(100*7%)	(100*10%)	(200*15%)

Figure 3. Calculation of Alternative Index Values

Based on the results of the above calculations, the results obtained from the calculation of the alternative index values of X1, X2 and X3 are presented in the form of table 11 for X1, table 12. For X2 and table.13 for X3 as follows.

Table 11. Results of Alternative Index Values of X1

Code	Alternative	Crtiteria										
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3
A1	Shell	8	7	5	5	6	8	60	5	7	10	60
A2	Fiber	8	7	5	5	6	8	45	5	7	10	45
A3	Empty fruit bunches	2	7	1,25	5	15	32	15	5	7	10	15
A4	POME	8	21	2,5	5	45	16	30	5	7	10	30

Table 12. Results of Alternative Index Values of X2

Code	Alternative	Crtiteria										
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3
A1	Shell	4	10,5	2,5	5	22,5	8	45	15	14	15	15
A2	Fiber	4	7	1,67	5	15	8	30	10	10,5	10	15
A3	Empty fruit bunches	8	7	1,67	5	22,5	8	15	5	14	10	15
A4	POME	4	14	5	5	15	8	45	10	7	15	15

Table 13. Results of Alternative Index Values of X3

Kode	Alternatif	Krtiteria										
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3
A1	Shell	8	7	5	5	15	8	15	5	7	10	15
A2	Fiber	8	7	5	5	15	8	15	5	7	10	15
A3	Empty fruit bunches	8	7	5	5	19,9	8	22,5	5	7	10	15
A4	POME	6	7	5	5	19,9	8	15	5	7	10	15

Combined index value calculation

After obtaining alternative index value data, then the value is calculated into a combined index value. By summing up each result of the value of the criteria for each criterion. The following calculation process is taken on the results of the alternative index value of respondent X1 marked with a green column in Figure 4.

CALCULATION OF COMBINED INDEX VALUES

Code	Alternative	CRITERIA											RESULTS
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3	
A1	Shell	8	7	5	5	6	8	60	5	7	10	60	181
A2	Fiber	8	7	5	5	6	8	45	5	7	10	45	151
A3	Empty fruit bunches	2	7	1,25	5	15	32	15	5	7	10	15	114,25
A4	POME	8	21	2,5	5	45	16	30	5	7	10	30	179,5

Figure 4. Combined Index Value Calculation Results of X1

The following is the calculation process to get the combined index value of X2.

CALCULATION OF COMBINED INDEX VALUES

Code	Alternative	CRITERIA											RESULTS
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3	
A1	Shell	4	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5	15	149,5
A2	Fiber	4	7	8	9	10	11	12	13	14	15	16	119
A3	Empty fruit bunches	8	7	1,67	5	22,5	8	15	5	14	10	15	111,17
A4	POME	4	14	5	5	15	8	45	10	7	15	15	143

Figure 5. Calculation of The Combined Index Value of X2

The following is the calculation process to get the combined index value of X3.

CALCULATION OF COMBINED INDEX VALUES

Code	Alternative	CRITERIA											RESULTS
		L1	L2	L3	E1	E2	E3	E4	E5	S1	S2	S3	
A1	Shell	8	7	5	5	15	8	15	5	7	10	15	100
A2	Fiber	8	7	5	5	15	8	15	5	7	10	15	100
A3	Empty fruit bunches	8	7	5	5	19,9	8	22,5	5	7	10	15	112,4
A4	POME	6	7	5	5	19,9	8	15	5	7	10	15	102,9

Figure 6. Calculation of The Composite Index Value of X3

Based on the calculation of the combined index values X1, X2 and X3, the results are then summed up based on the alternatives available to each respondent.

A1 = 181 + 156,5 + 100 = 437,5

A2 = 151 + 116,17 + 100 = 367,17

A3 = 114,25 + 117,17 + 112,4 = 343,82

A4 = 179,5 + 143 + 102,9 = 425,4

After summing up, ranking is carried out, the most prominent combined index value is the best alternative. The output of ranking based on the combined index value is in the form of a table as follows.

Table 14. Ranking

Code	Alternative	Composite performance index value	Rank
A1	Shell	437,5	1
A2	Fiber	367,17	3
A3	Empty fruit bunches	343,82	4
A4	POME	425,4	2

Based on table 14, there are the results of the ranking. Obtained Shell (A1) with a total value of 437.5 as the first rank, POME (A4) with a total value of 425.4 as the second rank, Fiber (A3) with a total value of 367.17 as the third rank and palm empty fruit bunches (A4) with a total value of 343.82 as the fourth rank. Therefore, the potential biomass to become a renewable energy source at the Sei. Buatan palm oil mill is Shells.

Conclusion

In the research carried out, it can be concluded that the biomass that can be used as a renewable energy source based on the ranking results using the CPI method is shell with a total value of 437.5, POME with a total value of 425.4, fiber with a total value of 367.17, and empty fruit bunches with a total value of 343.82. then the biomass that can be used as a renewable energy source is shell.

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