Analysis of Priority Bioavtur Raw Materials for Indonesia

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Abstract. Bioavtur is a liquid fuel produced from vegetable materials, organic materials, and/or organic waste processed through various specific process technologies for aviation turbine or jet engine fuel. Sustainable bioavtur raw materials in Indonesia come from crude palm oil, coconut oil, used cooking oil, palm oil liquid waste, agricultural residues, palm oil solid waste, sawdust, wood chips, urban waste, and molasses. This study aims to analyze the priority of bioavtur raw materials in accordance with potential availability, fuel technology developments, global technology implementation, emissions, and sustainability criteria. This study uses a multi-criteria decision analysis method using a simple multi-attribute rating technique extended to rank approach. This study found that crude palm oil and used cooking oil became the first and second priority as raw materials. This study also found that Indonesia has short-term, medium term-, and long-term readiness in terms of raw materials for bioavtur. In the short term, vegetable oil, especially palm-based, can be an option. Furthermore, in the medium term, where biomass is starting to become an option due to technological developments, Indonesia already has a variety of biomass sources that can be utilized. In the long term, when technology offers new options, Indonesia is also ready with other raw materials, including those based on glucose and lignocellulosic biomass.

1 Introduction

Bioavtur is a liquid fuel produced from plant materials, other organic materials, and/or organic waste processed through various specific process technologies for aircraft turbine or jet engine fuel[1]. In other words, bioavtur in Indonesia is an aviation fuel derived from sustainable sources, such as waste vegetable oil, used cooking oil, biomass waste, and others. Bioavtur is designed to replace conventional fossil-based aviation fuel, with the aim of reducing greenhouse gas emissions produced by the aviation industry. Some of the advantages of bioavtur include its environmental friendliness which can reduce carbon emissions by up to 80% compared to conventional fuels, the ability to use waste-based raw materials so that it is more sustainable, and its high compatibility which can be used in aircraft

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engines without requiring major modifications[2]. Bioavtur is currently an important part of the global effort to achieve carbon neutrality in the aviation industry even though the price of bioavtur is much higher due to its complex production process when compared to the price of fossil-based avtur. For example, the price of aviation fuel at Soekarno-Hatta Airport for domestic flights in December 2024 is expected to be around Rp 13,767 per liter. This presents a key challenge in developing bioavtur in Indonesia: how to reduce production costs to make it more competitive and allow widespread use without burdening consumers with soaring airfares [3].

The raw materials for bioavtur production must meet sustainability criteria so that they can be used without damaging or disrupting the environmental balance. Sustainable bioavtur raw materials typically meet several criteria: (1) they are based on waste or other renewable sources, which can be derived from waste cooking oil, biomass, agricultural waste, or other renewable resources such as algae and energy crops; (2) they do not disrupt food security or compete with food crops or cause detrimental land use changes; (3) they are environmentally friendly because they produce low carbon emissions; and (4) they comply with international technical and aviation safety standards such as ASTM D7566 so that they can be used in aircraft without major modifications [2].

To encourage the development of bioavtur, the Government has currently formulated a mandatory policy as stipulated in Minister of Energy and Mineral Resources Regulation Number 4 of 2025 concerning the Business and Utilization of Biofuels and the National Roadmap and Action Plan for the Development of the Bioavtur Industry, which mandates mandatory bioavtur use starting in 2027 with a percentage of 1-3%, with a target for pilot utilization at Soekarno-Hatta Airport in Jakarta and I Gusti Ngurah Rai Airport in Bali. This 3% mandate is estimated to only result in a 6-9% increase in aviation fuel prices [1]. The government is also committed to meeting the international Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) standards set by ICAO, which include certification of sustainable raw materials. These steps align with Indonesia's target of achieving net-zero emissions in the aviation sector by 2060, as well as utilizing the potential of local raw materials such as used cooking oil and palm residue [2].

The research aims to analyze the priority bioavtur raw materials based on potential availability, fuel technology developments, global technology implementation, emissions, and sustainability criteria. This research is expected to contribute to bioavtur development efforts, particularly the development of bioavtur from priority raw materials, namely used cooking oil (UCO) and palm acid oil (PAO) residue. These priority raw materials were chosen because UCO and PAO are renewable, abundant, and have a low Life Cycle Emission Factor (LCEF), thus aligning with ICAO policies regarding CORSIA. The Ministry of Energy and Mineral Resources (ESDM) recorded that national palm cooking oil consumption reached 16.2 million kiloliters (KL). Of this figure, the average used cooking oil produced is in the range of 40-60% or in the range of 6.46 - 9.72 million KL, although the used cooking oil that can be collected in Indonesia only reaches 3 million KL or only 18.5% of the total national palm cooking oil consumption. The availability of PAO in Indonesia can be approximated by the mass balance of palm oil which is estimated at around 0.91% of CPO. If in 2023, National CPO production reaches 47.08 million tons, then the availability of PAO is estimated to reach 0.428 million tons [4].

2 Methods

This analysis of bioavtur raw materials for Indonesia uses the multi-criteria decision analysis (MCDA) methodology, or decision-making with a multi-criteria approach. The MCDA method is used to assess the priority order of various alternatives by considering certain factors (as constraints in the selection). This method is widely used for decision-making, with varying levels of detail. Therefore, MCDA methods also have different techniques [5]. In this study, the aim was to determine the high potential of raw materials among the previously identified materials. Therefore, the MCDA method used was MCDA-SMARTER (simple multi-attribute rating technique extended to ranking), which is widely used for initial screening of alternatives and involves independent assessment criteria [5]. In the MCDA-SMARTER method, the alternatives being reviewed are scored based on predetermined criteria. The alternative with the highest compliance with the criteria is given a score of 10 (highest) and 1 (lowest) for very low compliance. Qualitatively formulated criteria are designed to be quantifiable and then used in calculating scores. In this method, the selected criteria are also assigned different weights. This is intended to highlight the priority of one criterion over another. Weighting is done systematically using the rank of centroid (ROC) method [6].

3 Result and Discussion

The selection of raw materials using the MCDA method is carried out by first selecting several types of raw materials that can and have the potential to be used. This is because some raw materials have a very dominant quantity compared to other raw materials in the same group. This indirectly has significantly reduced the opportunities for other materials. The materials reviewed are palm oil, coconut oil, used cooking oil, palm acid oil (PAO), palm oil harvesting residue biomass (Biomass of Palm), rice harvesting residue biomass (Biomass of Paddy), roundwood production residue biomass (Sawdust), particle-type processed wood production residue biomass (Woodchips), molasses, and the organic fraction of municipal solid waste (OFMSW). The processing technologies used to process the raw materials reviewed are derived from existing and future technologies, such as Hydroprocessed Esters and Fatty Acids (HEFA), Fischer-Tropsch (FT), Alcohol to Jet (ATJ), Catalytic Hydrothermolysis (CH), Hydroprocessed Depolymerized Cellulosic Jet (HDCJ), Direct Sugar Conversion to Hydrocarbons (DSHC), and Aqueous Phase Reforming (APR). Furthermore, assessment criteria for each of these raw materials need to be determined. To ensure a fast, yet focused selection process, the following criteria were selected. The first criteria is Raw Material Availability Criteria. This criterion is based on previously collected raw material quantity data. Within this criterion, score limits (1 and 10) are set, along with the production volumes of coconut oil (minimum) and palm oil (maximum). The second criteria is Global Technology Implementation Criteria. Global technology availability represents the development of bioavtur production technology at the global level. The development of this technology is expressed by the technology's readiness score for large-scale production (beyond laboratory experimentation). This technology readiness assessment is analyzed using data on technology availability at the scale-up level (including pilot plants and demonstrations), as well as the development of the technology's literature. The third criteria is Technology Availability Criteria in Indonesia. This criterion is necessary to assess the implementation of technologies that have been developed globally and are available in Indonesia. The scoring system for this criterion is based on the results of the Global Technology Availability Criteria assessment, to which assumptions regarding the adoption time for implementation in Indonesia are added.

The fourth criteria is Carbon Dioxide Emission Criteria. Regarding bioavtur production, the sustainability parameter, represented by the amount of CO2-equivalent, is a key factor in feedstock selection [2]. The fifth criteria is Sustainability Criteria. Sustainability is quantified using the life cycle emissions factor (LCEF) for a CORSIA eligible fuel, expressed in gCO2 e/MJ for each feedstock category [2]. The last criteria is Technology Flexibility Criteria. The criteria for suitability of raw materials to the technologies previously reviewed are based, in brief, on the number of technologies available for a given type of raw material. Assessments using the above criteria are conducted over several periods until the net zero carbon (NZC) target is met by 2060. 2060 is used as the end of the assessment period. The current year, 2025, is chosen as the starting year, but 2020 is considered representative of the period. This is used to simplify the division of the assessment period from 2020 to 2060 into 10-year intervals.

3.1 Scoring system in the MCDA method

In the MCDA method, parameters within a specific criterion are scored on a scale of 1-10. This range essentially serves to normalize parameter values, which can vary significantly across criteria. To convert a parameter value to a scale of 1-10, the smallest and largest values of the parameter are then converted using the following equation.

$$Score_{1\text{-}10} = 1+((10-1)(P-P_1)/(P_2-P_1)) \quad (1)$$

With a score of 1 to 10 being the result of converting parameter values into MCDA scores, P is the parameter value to be converted, P1 and P2 are the smallest and largest parameter values respectively.

3.1.1 Criteria for availability of raw materials

Table 1 shows the calculated scores for the raw material availability criterion. Scores ranging from 1 to 10 were calculated using a linearization method. Similar calculations were performed for the other two criteria (except the technology availability criterion).

Table 1. Results of raw material availability criteria score calculation.

No	Types Of Raw Materials	Amount, Tonnes	Score
1	Crude Palm Oil (CPO) [7]	47.084.299	10,00
2	Coconut Oil [8]	1.019.000	1,13
3	Used Cooking Oil (UCO) [9]	6.460.000	2,29
4	Palm Acid Oil (PAO) [10]	428.000	1,00
5	Biomass of Paddy [10]	36.830.277	8,80
6	Biomass of Palm Oil [10]	36.430.845	8,72
7	Sawdust [10]	14.253.635	3,96
8	Woodchips [10]	5.022.845	1,98
9	Molasses [10]	1.288.000	1,18
10	Organic Phase Municipal Solid Waste (OPMSW) [10]	15.673.240	4,27

In calculating this criterion, the addition of raw materials from 2030 to 2060 is linear extrapolated. There is no change in land use. UCO collection is increasingly widespread, but its use is also becoming more diverse for various needs, including export. However, because the quantity added through extrapolation remains constant, the normalized score will remain the same from year to year.

3.1.2 Global technology implementation criteria

The scoring of this criterion is based on the results of the scoring system in the technological development analysis section, where technologies that have high readiness will be linked to the choice of raw materials reviewed as shown in table 2. Raw materials will have a maximum score (score 10), if they have a technology choice that has reached the maturity scale level with a score of 10 (the highest). On the other hand, raw materials will be given a score of 1 if they are in the opposite condition, so that in this criterion, the score is only worth 1 and 10. Raw materials consist of 3 different types, namely vegetable oil, biomass and molasses or glucose. By assuming that one technology for a certain type of raw material can be used for other similar materials, as long as one of the technologies that can process vegetable oil/biomass/glucose has achieved the highest score, all raw materials that can be processed with that technology will be given a score of 10. By referring to the flexibility of raw materials to certain technologies, the results of the scoring for this criterion are as follows.

Table 2. Scoring results for the global technology implementation category.

Types Of Raw Materials	Scores				
	2020	2030	2040	2050	2060
Crude Palm Oil (CPO)	10	10	10	10	10
Coconut Oil	10	10	10	10	10
Used Cooking Oil (UCO)	10	10	10	10	10
Palm Acid Oil (PAO)	10	10	10	10	10
Biomass of Paddy	1	10	10	10	10
Biomass of Palm Oil	1	10	10	10	10
Sawdust	2,8	10	10	10	10
Woodchips	2,8	10	10	10	10
Molasses	1,6	1	1	10	10
Organic Phase Municipal Solid Waste (OPMSW)	1	10	10	10	10

In calculating this criterion, the addition of raw materials from 2030 to 2060 is extrapolated. However, because the quantity added through extrapolation remains constant, the normalized score will remain the same from year to year.

3.1.3 Technology availability criteria

This criterion assumes that the technology Indonesia will adopt to produce bioavtur is at a HEFA technology has been used in Indonesia to produce SAF current period, the scoring system is based on the estimated technology available in Indonesia. If the technology is available and used for bioavtur production, the raw materials that can be processed with that technology will be given a score of 10. If the technology is available but used for other purposes, it will be given a score of 5. If both aspects are not met, the raw materials will be given a score of 1.

Table 3. Technology availability criteria score calculation results.

No	Types Of Raw Materials	Technology Availability	Score
1	Crude Palm Oil (CPO)	HEFA technology has been used in Indonesia to produce SAF	10
2	Coconut Oil		10
3	Used Cooking Oil (UCO)		10
4	Palm Acid Oil (PAO)		10
5	Biomass of Paddy	FT and Gasification technology does not yet exist in Indonesia on an industrial scale	1
6	Biomass of Palm Oil		1
7	Sawdust		1
8	Woodchips		1
9	Molasses	HC Fermentation and Oligomerization processes are available but not yet used for SAF production.	5
10	Organic Phase Municipal Solid Waste (OPMSW)		5

For the period 2030 to 2060, the scoring system uses only the numbers 1 and 10. A raw material will be awarded a score of 10 if the technology capable of processing it has had the highest level of global implementation in the previous period. By this logic, all raw materials will receive a score of 10 starting in 2060.

3.1.4 CO_2 emission criteria

These emission criteria are based on the life cycle assessment (LCA) values as per CORSIA. In this calculation, the life cycle emission factor (LSf) values obtained from ICAO are used as the basis for the calculation. The similarity in LSf values is due to the fact that LSf values in ICAO (2022) are not always stated for each type of raw material, but rather for each group of raw materials. The main principle is the lower the LSf the higher the score. The calculation results are shown in Table 4.

Table 4. Sustainability criteria score calculation results.

No	Types Of Raw Materials	LSf (gCO2-e/MJ)	Score
1	Crude Palm Oil (CPO)	37,4	1
2	Coconut Oil	37,4	1
3	Used Cooking Oil (UCO)	13,9	8,12
4	Palm Acid Oil (PAO)	20,7	6,06
5	Biomass of Paddy	7,7	10
6	Biomass of Palm Oil	7,7	10
7	Sawdust	8,3	9,82
8	Woodchips	8,3	9,82
9	Molasses	27	4,15
10	Organic Phase Municipal Solid Waste (OPMSW)	5,2	10

During the period reviewed, from 2020 to 2060, it is assumed that the scores in Table 4 remain unchanged. Differences between periods are due to the priority of application of these criteria (represented by weighting factors).

3.1.5 Alternative technology criteria

Scoring for this criterion is conducted through qualitative analysis based on the selected raw materials and previous technology. Quantification is performed by constructing a matrix of raw material and technology suitability, as shown in Table 5. The number of checkmarks in a row is used as a simple indicator of the raw material's flexibility with technology. This criterion remains unchanged over time in the total calculation.

Table 5. SAF raw material and production technology suitability matrix.

No	Types of Raw Materials	Raw Material Suitability Score with SAF Production Technology						
		HEFA	FT	ATJ	CH	HDCJ	DSHC	ARP
1	Crude Palm Oil (CPO)	v			v			
2	Coconut Oil	v			v			
3	Used Cooking Oil (UCO)	v			v			
4	Palm Acid Oil (PAO)	v			v			
5	Biomass of Paddy		v		v	v		
6	Biomass of Palm Oil		v		v	v		
7	Sawdust		v		v	v		
8	Woodchips		v		v	v		
9	Molasses			v			v	v
10	Organic Phase Municipal Solid Waste (OPMSW)		v				v	

Based on the simple quantification in Table 5, the assessment results can be shown in Table 6 below.

3.1.6 Global technology implementation criteria

The scoring of this criterion is based on the results of the scoring system in the technological development analysis section, where technologies that have high readiness will be linked to the choice of raw materials reviewed as shown in table 2. Raw materials will have a maximum score (score 10), if they have a technology choice that has reached the maturity scale level with a score of 10 (the highest). On the other hand, raw materials will be given a score of 1 if they are in the opposite condition, so that in this criterion, the score is only worth 1 and 10. Raw materials consist of 3 different types, namely vegetable oil, biomass and molasses or glucose. By assuming that one technology for a certain type of raw material can be used for other similar materials, as long as one of the technologies that can process vegetable oil/biomass/glucose has achieved the highest score, all raw materials that can be processed with that technology will be given a score of 10. By referring to the flexibility of raw materials to certain technologies, the results of the scoring for this criterion are as follows.

Table 6. Raw material suitability matrix and production technology quantity.

No	Types Of Raw Materials	Amount of Technology	Score
1	Crude Palm Oil (CPO)	2	2,86
2	Coconut Oil	2	2,86
3	Used Cooking Oil (UCO)	2	2,86
4	Palm Acid Oil (PAO)	2	2,86
5	Biomass of Paddy	3	4,29
6	Biomass of Palm Oil	3	4,29
7	Sawdust	3	4,29
8	Woodchips	3	4,29
9	Molasses	3	4,29
10	Organic Phase Municipal Solid Waste (OPMSW)	3	4,29

The assessment results presented in Tables 2 through 6 are then combined in Table 7 and multiplied by the weighting factor. In this analysis, the weighting factor represents the priority or ranking of the five criteria used. The rank of centroid (ROC) method used to calculate the weighting factor can be expressed as follows.

$$Wi = 1/n \sum_{k=i}^{n} \frac{1}{k} \qquad (1)$$

As an example calculation, Table 7 shows the results of a review of the weighting factor calculations at the top of the table (for 2020). These weighting factors are then used to multiply the scores of the raw material criteria in the same column.

3.1.7 Global technology implementation criteria

The scoring of this criterion is based on the results of the scoring system in the technological development analysis section, where technologies that have high readiness will be linked to the choice of raw materials reviewed as shown in table 2. Raw materials will have a maximum score (score 10), if they have a technology choice that has reached the maturity scale level with a score of 10 (the highest). On the other hand, raw materials will be given a score of 1 if they are in the opposite condition, so that in this criterion, the score is only worth 1 and 10.

Raw materials consist of 3 different types, namely vegetable oil, biomass and molasses or glucose. By assuming that one technology for a certain type of raw material can be used for other similar materials, as long as one of the technologies that can process vegetable Availability of Alternative with that technology will be given a score of 10.

In this analysis, weights are calculated using the Rank Order Centroid (ROC) weighting formula.

$$Wk = 1/k \sum 1/i \quad (1)$$

The weighting in the ROC method uses a range between 0 and 1, simplifying the calculation and comparison of values for each alternative. ROC is based on the importance or priority of the criteria. The ROC technique assigns weights to each criterion according to its ranking, assessed based on priority level. Based on expert consultation with PT. Pertamina Indonesia Refinery and Tripatra, the highest priority is global technology implementation, followed by availability of raw materials, availability of technology, CO2 Emission, and alternative technology.

By referring to the flexibility of raw materials to certain technologies, the results of the scoring for this criterion are as follows.

Table 7. Example of Weighting Factor Calculation Results for Each Criteria.

CO2 Emission Technology

NO	Types of Raw Materials	WEIGHTING FACTOR				
		0,26	0,46	0,15	0,09	0,04
		SCORES				
		Availability of Raw Materials	Global Technology Implementation	Availabilty of Technology	CO2 Emission	Alternative
1	Crude Palm Oil (CPO)	10,00	10	10	1	3,25
2	Coconut Oil	1,13	10	10	1	3,25
3	Used Cooking Oil (UCO)	2,29	10	10	7,57	3,25
4	Palm Acid Oil (PAO)	1,00	10	10	5,65	3,25
5	Biomass of Paddy	8,80	1	1	9,3	5,5
6	Biomass of Palm Oil	8,72	1	1	9,13	5,5
7	Sawdust	3,96	2,8	1	10	5,5
8	Woodchips	1,98	2,8	1	10	5,5
9	Molasses	1,18	1	5	5,5	5,5
10	Organic Phase Municipal Solid Waste (OPMSW)	4,27	1	5	3,91	5,5

The product of the weighting factor and each score is the final score of the MCDA analysis for the parameter under consideration. In this case, an example of the calculation results is shown in Table 8.

3.1.8 Global technology implementation criteria

The scoring of this criterion is based on the results of the scoring system in the technological development analysis section, where technologies that have high readiness will be linked to the choice of raw materials reviewed as shown in table 2. Raw materials will have a maximum score (score 10), if they have a technology choice that has reached the maturity scale level with a score of 10 (the highest). On the other hand, raw materials will be given a score of 1 if they are in the opposite condition, so that in this criterion, the score is only worth 1 and 10. Raw materials consist of 3 different types, namely vegetable oil, biomass and molasses or glucose. By assuming that one technology for a certain type of raw material can be used for other similar materials, as long as one of the technologies that can process vegetable oil/biomass/glucose has achieved the highest score, all raw materials that can be processed with that technology will be given a score of 10. By referring to the flexibility of raw materials to certain technologies, the results of the scoring for this criterion are as follows.

Table 8. Example of Final MCDA Score Calculation Results.

NO	types of raw materials	Availability of Raw Materials	Global Technology Implementation	Technology Availability	CO2 emissions	Alternatives	Total
1	Crude Palm Oil (CPO)	2,60	4,60	1,50	0,09	0,13	8,92
2	Coconut Oil	0,29	4,60	1,50	0,09	0,13	6,61
3	Used Cooking Oil (UCO)	0,60	4,60	1,50	0,68	0,13	7,51
4	Palm Acid Oil (PAO)	0,26	4,60	1,50	0,51	0,13	7,00
5	Biomass of Paddy	2,29	0,46	0,15	0,84	0,22	3,96
6	Biomass of Palm Oil	2,27	0,46	0,15	0,82	0,22	3,92
7	Sawdust	1,03	1,29	0,15	0,90	0,22	3,59
8	Woodchips	0,52	1,29	0,15	0,90	0,22	3,07
9	Molasses	0,31	0,46	0,75	0,50	0,22	2,23
10	Organic Phase Municipal Solid Waste (OPMSW)	1,11	0,46	0,75	0,35	0,22	2,89

In addition to assessing the potential of raw materials under current conditions, the MCDA is expected to also represent the development of bioavtur production technology through 2060, which will undoubtedly influence the selected raw material yields. Changes and developments leading up to 2060 are further represented by shifting the priority criteria, in addition to using the previous technological development analysis. These priority changes are as follows:

a. In the initial period (2022 or 2020), the highest priority is technology availability in Indonesia, followed by raw material availability as the second priority. During this period, CO2 production from technology remains the fourth priority, after global technology implementation. The consideration chosen in this situation is prioritizing bioavtur production with existing technology, albeit in relatively small quantities. The raw materials used in the initial phase, despite having low LCA scores, are still

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used to ensure that the progress of bioavtur production in Indonesia can become the foundation for subsequent developments.

b. The ranking for raw material availability was subsequently revised to first priority from 2030 to 2060. This consideration was based on the projected increasing demand for bioavtur, making raw material availability a crucial factor.

c. The criteria related to CO2 production were gradually raised in ranking to first place by 2060. The basis for this selection was to provide Indonesia with the opportunity to continue producing bioavtur using available raw materials, while simultaneously adopting and developing process technology in line with global technological developments.

From the various calculations performed, the final MCDA assessment score is shown in Figure 1. With the availability of vegetable oil-based raw materials (palm) and HEFA technology, which is already widely used globally, Indonesia can realize domestic bioavtur production to continue the milestones already achieved. However, with the increasing demand for bioavtur and the demand for more environmentally friendly processes, biomass-based processes need to be an alternative. Biomass is starting to become an option because technological developments are increasingly mature and Indonesia already has a variety of biomass sources that can be utilized. The use of vegetable oil-based processes remains the primary choice until 2030. It is hoped that, with the increasing development of biomass conversion technology globally, Indonesia's biomass potential can begin to be utilized from 2040 onwards.

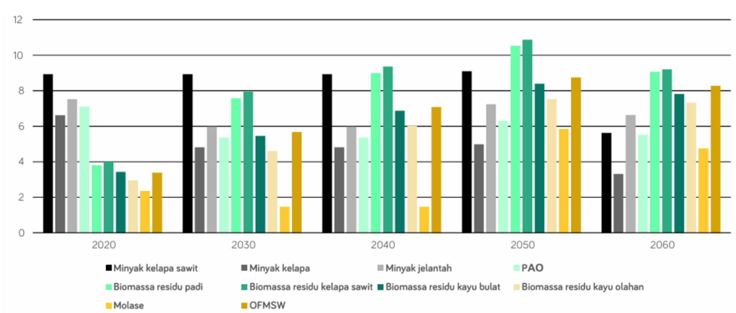

Fig. 1. Results of the Assessment of Bioavtur Raw Material Potential Using the MCDA Method from 2020 to 2060.

4 Conclusion

The MCDA analysis presented in Tables 1 through 8 above indicates that palm oil has the highest total score of 8.920, meaning palm oil is currently the top priority for bioavtur raw materials. The next priority is used cooking oil with a total score of 7.523. The third priority is PAO with a score of 7.100. The final priority is molasses with the lowest total score of 2.356. The MCDA assessment of bioavtur raw material potential from 2020 to 2060, as shown in Figure 1, attempts to assess the feasibility of raw materials based on various criteria for bioavtur production in Indonesia. The assessment results, of course, still need to be reviewed and tested using more detailed criteria that are representative of actual conditions. Nevertheless, these results can provide some information about Indonesia's readiness in the short, medium, and long term for bioavtur raw materials. In the short term, vegetable oils, particularly palm-based ones, can be an option. Furthermore, in the medium term, As biomass has become an option due to technological advances, Indonesia already has a variety of biomass sources available for use. In the long term, as technology offers new options, Indonesia is also ready with other raw materials, such as glucose-based and non-lignocellulosic biomass.

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