Journal of Mechanical Design and Testing 7(2), (2025), 93-101
DOI: 10.22146/jmdt.114911
e-ISSN: 2685-8029, ISSN: 2716-1293

Utilization of AHP-TOPSIS Combination to Determine The Best Biomass Dryer Technology at Pelabuhan Ratu CFPP

H. Hermawan*

Engineering Department, PT. PLN Indonesia Power, Indonesia
*E-mail: heru.hermawan@plnindonesiapower.co.id

Abstrak

Tantangan utama dalam penerapan *co-firing* biomassa di PLTU Pelabuhan Ratu adalah tingginya kadar air dan rendahnya nilai kalor biomassa (serbuk gergaji). Karakteristik biomassa tersebut menyebabkan produksi energi hijau menjadi rendah meskipun tingkat pemanfaatan biomassa cukup tinggi. Sementara itu, target produksi energi hijau terus meningkat setiap tahunnya sesuai dengan *Cofiring Roadmap* PT PLN. Penelitian ini berfokus pada pemilihan jenis pengering biomassa dengan menggunakan metode *Multi-Criteria Decision Making (MCDM)*, yang mencakup tiga alternatif yaitu *rotary dryer*, *packed moving bed dryer*, dan *flash dryer*. Metode yang digunakan adalah *Analytical Hierarchy Process (AHP)* dan *Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)* dengan empat kriteria dan delapan subkriteria. Sebanyak tujuh orang ahli diminta untuk mengisi kuesioner penilaian kriteria sebagai input dalam analisis AHP. Selain itu, dikumpulkan pula data pendukung seperti data operasional, manajemen risiko, hasil diskusi internal, studi literatur, dan sumber relevan lainnya. Hasil AHP menunjukkan tiga kriteria utama dengan bobot global tertinggi, yaitu Karakteristik Biomassa (28,1%), Keselamatan (*Safety*) (20,5%), dan Lingkungan (17,8%). Berdasarkan perhitungan TOPSIS, *rotary dryer* terpilih sebagai alternatif terbaik untuk pengering biomassa. Selanjutnya, dilakukan uji sensitivitas dengan mengubah bobot dari tiga kriteria utama tersebut sebesar -25% dan +25%. Hasil uji menunjukkan bahwa *rotary dryer* secara konsisten tetap menjadi alternatif terbaik.

***Kata kunci**: AHP, pengering biomassa, nilai kalor, kadar air, TOPSIS*

Abstract

The main challenge of biomass cofiring at Pelabuhan Ratu Power Plant is the high moisture and low calorific value of the biomass (sawdust). This biomass characteristic causes low green energy production despite high biomass utilization. Meanwhile, the green energy production target continues to increase in the upcoming year, according to PLN's Cofiring Roadmap. This research focuses on the selection of biomass dryers using Multi-Criteria Decision Making, including rotary dryers, packed moving bed dryers, and flash dryers. The method used was the Analytical Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) using four criteria and eight sub- criteria. Seven experts were asked to complete the criteria ranking questionnaire for AHP input. Other relevant data were also collected, such as operational data, risk management, internal discussions, literature studies, and others. The top 3 criteria with the highest global weight (AHP results) are Biomass Characteristics (28.1%), Safety (20.5%), and Environment (17.8%). TOPSIS calculation resulted in the rotary dryer being the best alternative biomass dryer. Furthermore, a sensitivity test was conducted by changing the weight of each of the top 3 criteria by -25% and +25%. The results show that the rotary dryer is consistently the best alternative.

***Keywords**: AHP, Biomass Dryer, Calorific Value, Moisture, TOPSIS.*

1. INTRODUCTION

The issue of global warming has become the most discussed issue in the world in recent years. Human dependence on fossil energy has long been believed to impact climate change severely (Pang, 2014). Every country is committed to reducing greenhouse gas (GHG) emissions and other measures in line with the impacts of climate change. The target is to achieve Net Zero emissions (NZE) by 2060. Through the Ministry of Energy and Mineral Resources (MEMR), the Indonesian government stated that Indonesia would seek a breakthrough in biomass utilization. One of the programs encouraged is using biomass cofiring as a substitute for coal in power plants. The cofiring program in steam power plants (PLTU) is included in the 2019-2038 National Electricity General Plan (Pribadi, 2020). PT PLN (Persero) has made a roadmap for biomass cofiring in Indonesia, as shown in Figure 1. In 2025, the most significant increase in biomass cofiring targets is 10.2 MTon biomass consumption and 12.71 TWh green energy production, as shown in Figure 1 (PT PLN [Persero], 2021).

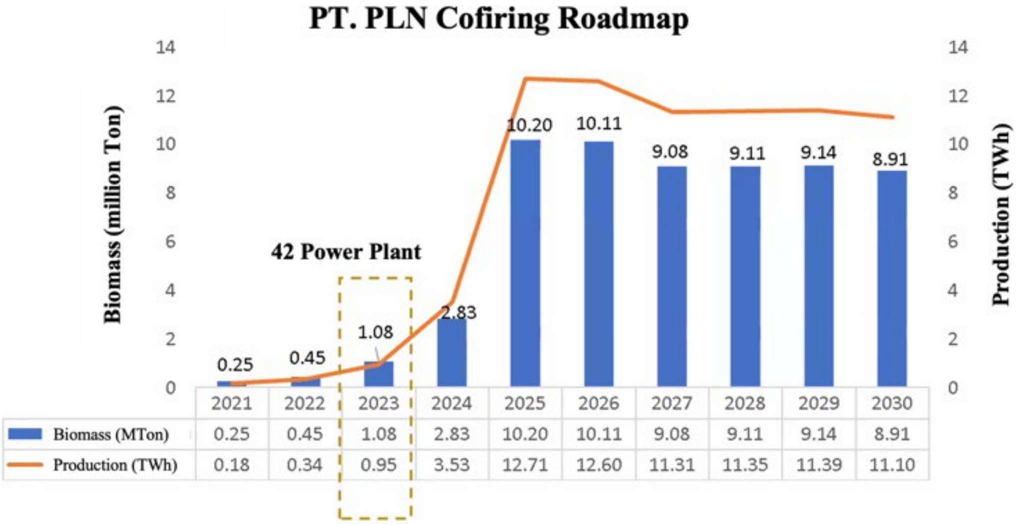

Figure 1. PT. PLN Cofiring Roadmap

PT PLN Indonesia Power Pelabuhan Ratu Power Plant has been conducting biomass cofiring using sawdust since 2020. The sawdust supplied to Pelabuhan Ratu Power Plant has a 50-70% moisture content range and a calorific value of 1,400- 2,200 kcal/kg. The total moisture of sawdust supplied to PLTU Pelabuhan Ratu is high, while the calorific value is low. As a result, the green energy production from biomass cofiring at Pelabuhan Ratu Power Plant is lower than other power plants, even though the volume of sawdust usage in Pelabuhan Ratu Power Plant is high.

In 2022, the Pelabuhan Ratu Power Plant has produced 5,440 MWh of green energy using 10,243 tons of biomass. In comparison, Rembang Power Plant produced 7,501 MWh using 6,888 tons of biomass, and Adipala Power Plant produced 6,232 MWh using 6,925 tons of biomass. The Rembang and Adipala Power Plants use biomass with less than 50% total moisture. Also, for comparison, Lontar Power Plant uses biomass with 50% total moisture and a calorific value of 3,261 kcal/kg. Pacitan Power Plant uses biomass with a total moisture of 35% and a calorific value of 3,000 kcal/kg. The influence of total moisture and calorific value of biomass on the realization of green energy production at the Power Plant is obvious.

In general, the moisture content of biomass is very high in its raw state. Therefore, biomass must be dried before being used as cofiring fuel to improve efficiency and energy quality and reduce emissions. Pang & Mujumdar (2010) found that boiler energy efficiency increased by 5-10% when using dry biomass compared to wet biomass (PT PLN [Persero], 2022), (Pang and Mujumdar, 2010).

High moisture content in coal and biomass fuels will cause incomplete combustion in the boiler. This high moisture content impacts the heating value, decreasing it dramatically, increasing the need for excess air, reducing power production, increasing transportation costs, and requiring special attention for biomass storage (Verma *et al.*, 2017). A higher biomass ratio will decrease CO2 emission and efficiency (Stenström, 2017). Higher total moisture will cause lower boiler thermal efficiency. Previous research has been conducted by comparing the thermal efficiency of boilers when using biomass with moisture variations of 10% to 60%. As a result, the boiler's thermal efficiency dropped by 7.5% when using biomass with 60% moisture (Wicaksono, 2021).

The drying process is a complex process involving transferring heat and mass at a particular process rate. Heat flows convectively from the heat source to the material's surface, then conductively into the material. Moisture (liquid phase) evaporates when there is sufficient heat, and then moisture (vapor phase) moves in the opposite direction to the direction of heat flow (from the inside to the surface of the material) (Pang and Mujumdar, 2010). Drying is the process of removing moisture through heat treatment to obtain a solid product (Dzurenda & Banski, 2017). The biomass drying process occurs at temperatures of 100-200°C where moisture (liquid phase) leaves the material in the vapor phase. The optimum moisture content is usually around 10- 25% (PT PLN [Persero], 2022), (Pang and Mujumdar, 2010), (Mujumdar, 2014), (Klass, 1998).

In the food, agriculture, forest, and biomass industries, drying is one of the most widely used methods to reduce moisture content. On an industrial scale, three types of biomass dryers are most widely used: packed moving bed dryers, rotary dryers, and pneumatic or flash dryers (Pang, 2014). Vigants et al. (2015) also mentioned that the most suitable dryers for sawdust are belt dryers, rotary dryers, and pneumatic dryers, which provide the lowest operational costs (Murugan *et al.*, 2021). In general, these three types of dryers are technologically mature enough to be implemented in power plants. Therefore, this research will focus on three types of dryers: rotary dryers, packed moving bed dryers, and pneumatic or flash dryers.

This research uses Multi-Criteria Decision-Making (MCDM) to determine the best alternative because it can provide solutions involving many independent criteria. This research uses the MCDM methods, namely the Analytical Hierarchy Process (AHP) and Technique for Others Preference by Similarity to Ideal Solution (TOPSIS). Decision-makers commonly use the combination of AHP and TOPSIS to solve problems. AHP is commonly used to solve complex problems. Saaty introduced the AHP method around the 1970s (Vigants et al., 2015). The AHP model decomposes complex multi-criteria problems into a hierarchy. According to Saaty, a *hierarchy* can be defined as a representation of a problem in a multilevel structure. The first level is objective, followed by the level of criteria, sub-criteria, and alternatives (Saaty, 1980). AHP pays excellent attention to consistency and measurement of this consistency and dependencies within and between the criteria of its structural elements (Arianto, 2021). TOPSIS uses a simple mathematical formula to measure the relative performance of decision alternatives.

The combination of AHP and TOPSIS methods provides a higher level of confidence to decision-makers, where these methods provide a systematic and scientific selection process (Saaty & Vargas, 2012). Sensitivity analysis was conducted to test the results obtained from the TOPSIS method. Saltelli et al. define sensitivity as a way to ascertain how a model (numerical or otherwise) depends on its input factors (Arep et al., 2021). This method assesses the stability of the preference values obtained (Saltelli et al., 2005). Sensitivity analysis is carried out after obtaining the preference value of each alternative. The sensitivity analysis process begins by changing the weight variation of each criterion obtained from the AHP process (Saltelli et al., 2005), (Bhadra et al., 2022).

A literature review on dryer technology has been conducted to find information on what criteria are considered important in selecting a dryer, as shown in Table 1.

This research focuses on selecting a suitable dryer to overcome the problems caused by high moisture content in biomass. In addition, this research is also directed to anticipate higher corporate targets starting from 2025. The hope for the future is that suitable dryers will reduce the moisture content of biomass so that green energy production can increase. From the author's literature review, no research explicitly discusses the selection of biomass dryers using the Multi-Criteria Decision-Making approach.

2. METHODS

This research utilized AHP and TOPSIS methods with four main criteria and eight sub-criteria from previous literature reviews (Table 1). Figure 2 shows the sequence of the calculation process.

Figure 2. Sequence of data processing

Table 1. Literature review of dryer technology and its criteria

No.	Literature Title	Criteria	Reference
1	Principles, Classification, and Selection of Dryers	Operational mode, biomass characteristic, biomass moisture quality parameter, safety aspect, cost, VOC emission, space requirement	Mujumdar (2014)
2	Industrial and Small-Scale Biomass Dryers: An Overview	Biomass characteristic, drying temperature, heat sources, energy consumption, cost, space requirement	Murugan et al. (2021)
3	Biomass Drying for an Integrated Bioenergy Plant	Energy efficiency, VOC emission, safety aspect	Pang (2014)
4	Dryer Selection Using Multi-Criteria Decision-Making (AHP)	Biomass characteristic, drying temperature, heat source, ability to handle wet biomass, cost, maintainability, capacity, inlet & outlet moisture	Saaty (1980); Saaty & Vargas (2012)
5	Biomass Drying and Dewatering for Clean Heat & Power	Biomass characteristic, cost, operation & maintenance, VOC emission, energy efficiency, heat source, space requirement, safety aspect, corrosion & erosion, by-products	Verma et al. (2017)
6	Report on Biomass Drying Technology	VOC emission, safety aspect, biomass characteristic, integration possibility with existing system, heat source, cost	Klass (1998)
7	Improving Energy Efficiency Through Biomass Drying	Heat source, energy efficiency, VOC emission, boiler dimension & capacity, cost, biomass characteristic, energy consumption	Stenström (2017)
8	Selection of an Appropriate Biomass Burner Using Analytic Hierarchy Process	Energy efficiency, design aspect (durability, mobility, ease of fabrication, versatility, ease of use), cost	Saaty (1980); Saaty & Vargas (2012)

A. Analytical Hierarchy Process (AHP)

The steps of AHP calculation can be seen in Figure 3 (details in supplementary section). In this research, AHP calculation uses *SuperDecision ver.3.2 software*. Criteria weighting is considered consistent if the CR value is less than 0.1. Consistency Ratio (CR) is a measure used to assess the consistency of the judgments made during the pairwise comparison process. Consistency ensures that the pairwise comparisons and resulting priorities make logical sense. High consistency means that the judgments align with the underlying logic of the comparisons. This improves the reliability and validity of the final decision.

The AHP hierarchy structure in this research is shown in Figure 4 & 5. Primary data collection in this study was carried out using a questionnaire method. The questionnaire has been submitted to seven expert respondents with at least ten years of experience working in power plants and biomass cofiring. Secondary data were obtained from equipment specification data, operational data, company data, corporate risk management, literature, textbooks, technical reports, and other relevant data.

Figure 3. Sequence of AHP Methods

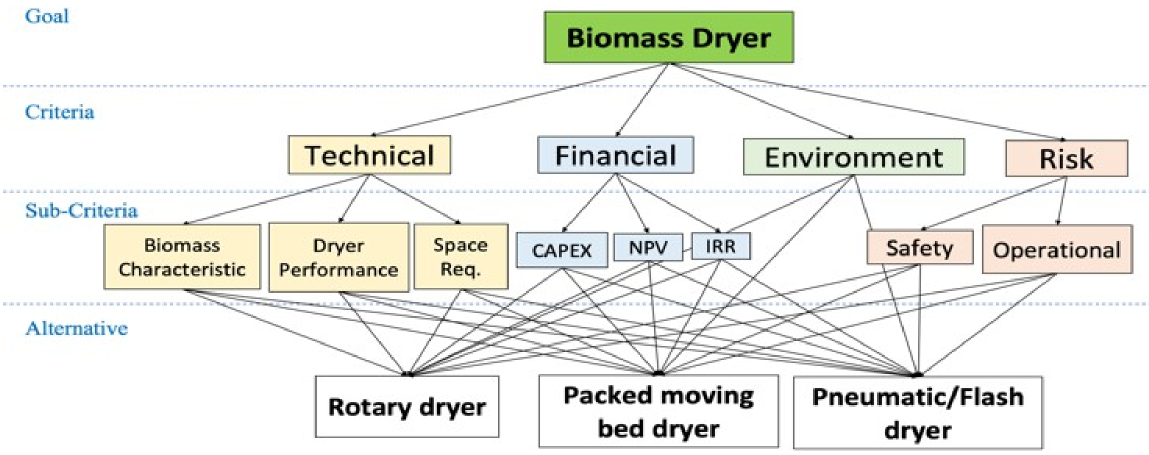

Figure 4. AHP Hierarchy Structure

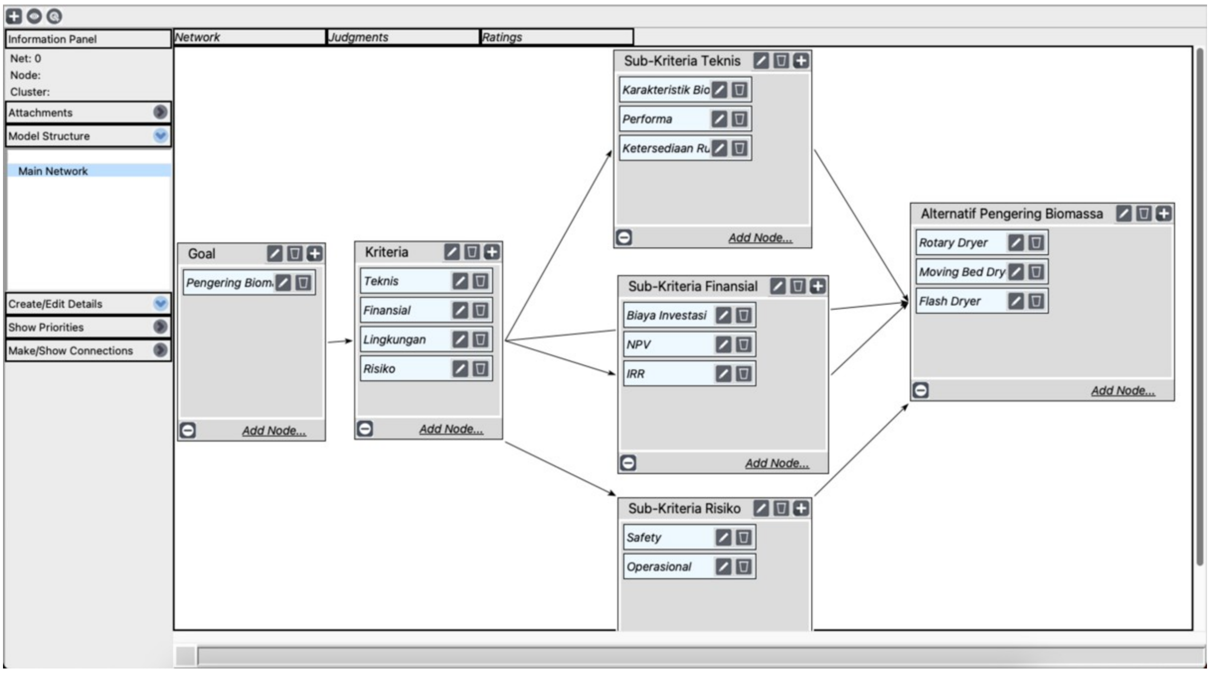

Figure 5. AHP Hierarchy Structure (SuperDecision Software)

B. Technique for Others Preference by Similarity to Ideal Solution (TOPSIS)

As shown in Figure 6, with the TOPSIS method, a series of calculations will be carried out, such as normalization of the decision matrix, weighting, calculation of best and worst ideal value, calculation of positive and negative ideal solution distance, and calculation of preference score to rank alternatives (details in supplementary section). The weight of each criterion is used in the TOPSIS method to obtain a ranking of the preference values of all alternatives. Then, a sensitivity analysis is carried out to ensure the results are robust and consistent.

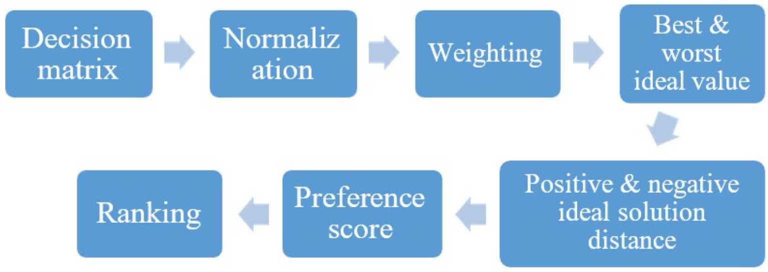

Figure 6. Sequence of TOPSIS Methods

C. Sensitivity Analysis

Sensitivity analysis was conducted to test the robustness of the AHP-TOPSIS results. The analysis was carried out by changing the criteria weights by +25% and -25% against the original weights. This weight variation range follows previous research by Saltelli et al. and Salwa et al. (Arep *et al.*, 2021), (Tian *et al.*, 2016). Weight variation is only done on 3 criteria with the highest global weight.

3. RESULTS AND DISCUSSION

A. Analytical Hierarchy Process (AHP)

Figure 7 is an example of a pairwise comparison matrix from one of the respondents. The Consistency Ratio (CR) is 0.034, which means it is considered consistent. The criteria weights of respondent #1 are technical 0.53664, financial 0.06275, environmental 0.22271, and risk 0.17340. Then, all respondents' weights of criteria and sub-criteria were calculated with the same steps. After that, global weights were calculated to determine the global ranking of all criteria and sub-criteria. The results are summarized in Table 2.

Table 2 shows the weight of each criterion and sub-criteria and then calculated the global weight. It is found that the highest global weight is the Biomass Characteristics criteria of 28.1%, the second is the Safety criteria of 20.5%, the third is the Environmental criteria of 17.8%, and the fourth is the Performance criteria of 14.9%. The rest of the global weight values are in the range of 3-5%.

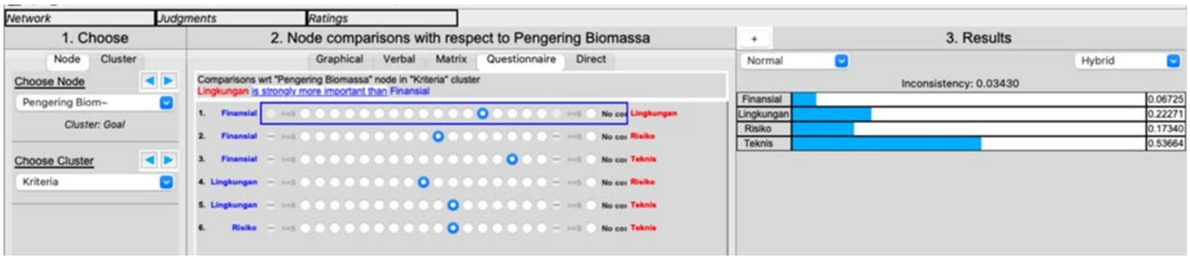

Figure 7. Example of Criteria Weighting of Respondent #1

Table 2. Global Weight and Ranking

Criteria	Sub-Criteria	Weight Criteria (a)	Weight Sub-Criteria (b)	Global (c) = (a × b)	Global Ranking
Teknis	Biomass Characteristic	0.489	0.575	0.281	1
	Performance		0.304	0.149	4
	Space Requirement		0.121	0.059	5
Finansial	CAPEX	0.094	0.094	0.009	9
	NPV		0.582	0.055	6
	IRR		0.324	0.031	8
Lingkungan	–	0.178	–	0.178	3
Risiko	Safety	0.238	0.858	0.205	2
	Operational		0.142	0.034	7

B. Technique for Others Preference by Similarity to Ideal Solution (TOPSIS)

Table 3 is the decision matrix used in the TOPSIS calculation. The decision matrix is obtained from power plant operational data, mass and energy balance calculations, company risk management, and literature studies. The benefit attribute means that if the criterion has a higher value, it is better. The cost attribute means that it is better if the criterion has a smaller value.

Table 4 shows the ideal solution distance of each alternative. The smallest positive ideal solution distance represents the alternative that is very close to the positive ideal solution and tends to be selected. Meanwhile, the largest positive ideal solution distance represents the alternative far from the positive ideal solution and tends not to be selected. The distance of the negative ideal solution applies the other way around. The smallest negative ideal solution distance tends not to be selected, and the largest tends to be selected

In determining the priority of alternatives, the preference score of each alternative is calculated using the ideal solution distance obtained in the previous stage. The smaller the distance of the positive ideal solution and the greater the distance of the negative ideal solution, the higher the priority to be selected.

The higher an alternative's preference score (V), the more prioritized the alternative is to be selected. From Table 5, it is found that the rotary dryer alternative has the greatest preference score of 0.569 (Rank 1), followed by the moving bed dryer alternative with a value of 0.437 (Rank 2), and the lowest is the pneumatic/flash dryer alternative with a value of 0.431 (Rank 3).

Table 3. Decision Matrix

	Technical			**Financial**				**Risk**	
Sub-Criteria	Biomass Characteristic	Performance	Space Req.	CAPEX (Billion IDR)	NPV (Billion IDR)	IRR (%)	**Environment**	Safety	Operational
Rotary dryer	4	5	4	2.70	9.21	57.78	3	2	3
Moving bed dryer	3	4	4	2.90	8.73	51.19	2	2	3
Pneumatic/flash dryer	2	4	3	3.70	6.52	29.39	2	1	3
Attribute	*Benefit*	*Benefit*	*Cost*	*Cost*	*Benefit*	*Benefit*	*Cost*	*Cost*	*Cost*

C. Sensitivity Analysis

Based on Table 2, the Top 3 highest global weights are Biomass Characteristics at 28.1%, Safety at 20.5%, and Environment at 17.8%. These three criteria weights were changed one by one by -25% and +25% from the original weights, and then the preference score and new ranking were calculated.

From Table 6 above, the sensitivity analysis shows that the rotary dryer alternative is consistently ranked 1. Meanwhile, ranks 2 and 3 have changed along with the changing weights of the three criteria. If we observe, the preference value of rank 2 and 3 is only 0.006 difference. It means that ranks 2 and 3 are in a reasonably close position, so changes can occur if there is a change in weighting. Therefore, decision-making in this study is consistent.

Table 4. Positive (D+) and Negative (D-) Ideal Solution Distance

Positive Ideal Solution Distance (D^+)	Rotary dryer	0,08130
	Moving bed dryer	0,08865
	Pneumatic/flash dryer	0,10728
Negative Ideal Solution Distance (D^-)	Rotary dryer	0,10728
	Moving bed dryer	0,06883
	Pneumatic/flash dryer	0,08130

Table 5. Preference Score (V)

Alternative	Preference Score (V)	Ranking
Rotary dryer	0,569	1
Moving bed dryer	0,437	2
Pneumatic/flash dryer	0,431	3

Table 6. Summary of Alternative Ranking on Sensitivity Analysis

Criteria / Sub-Criteria	Original Ranking	Biomass Characteristic		Safety		Environment	
		–25% Ranking	+25% Ranking	–25% Ranking	+25% Ranking	–25% Ranking	+25% Ranking
Rotary dryer	1	1	1	1	1	1	1
Moving bed dryer	2	3	3	2	3	3	2
Pneumatic/flash dryer	3	2	2	3	2	2	3

4. CONCLUSION

The MCDM method, with a combination of AHP and TOPSIS, can assist in selecting the best biomass dryer. The criteria and sub-criteria used were developed based on the literature study. Four main criteria are used: technical, financial, environmental, and risk. The top 3 highest global weights are Biomass Characteristics at 28.1%, Safety at 20.5%, and Environment at 17.8%. TOPSIS calculation has resulted in the first rank being rotary dryer, followed by second rank moving bed dryer, and third rank pneumatic/flash dryer. Sensitivity analysis has also been conducted to ensure consistency of results by changing the Top 3 highest global weights. The weighting of the three criteria was changed (±25%), and consistent results were obtained, with the rotary dryer as rank 1.

5. REFERENCES

Arep, H., et al. (2021). Selection of conceptual design for spin grind dryer seaweed powder machine. *International Journal of Computer Information Systems and Industrial Management Applications (IJCISIM), 13*, 266–274.

Arianto, A. (2021). *Pemilihan alternatif co-firing PLTU batubara untuk penurunan gas rumah kaca dengan metode DEMATEL dan AHP pada PT Pembangkitan XYZ* [Undergraduate thesis, Institut Teknologi Sepuluh Nopember]. ITS Repository.

Bhadra, D., Dhar, N. R., & Salam, M. A. (2022). Sensitivity analysis of the integrated AHP-TOPSIS and CRITIC-TOPSIS method for selection of the natural fiber. *Materials Today: Proceedings, 56*, 2618–2629. https://doi.org/10.1016/j.matpr.2021.09.178

Dzurenda, L., & Banski, A. (2017). Influence of moisture content of combusted wood on the thermal efficiency of a boiler. *Archives of Thermodynamics, 38*(1), 63–74. https://doi.org/10.1515/aoter-2017-0004

Klass, D. L. (1998). *Biomass for renewable energy, fuels, and chemicals*. San Diego, CA: Academic Press.

Mujumdar, A. S. (2014). Principles, classification, and selection of dryers. In A. S. Mujumdar (Ed.), *Handbook of Industrial Drying* (4th ed.). Boca Raton, FL: CRC Press.

Murugan, P., Dhanushkodi, S., Sudhakar, K., & Wilson, V. H. (2021). Industrial and small-scale biomass dryers: An overview. *Energy Engineering, 118*(3), 435–446. https://doi.org/10.32604/EE.2021.013491

Pang, S. (2014). Biomass drying for an integrated bioenergy plant. In A. S. Mujumdar (Ed.), *Handbook of Industrial Drying* (4th ed., pp. 847–860). Boca Raton, FL: CRC Press. https://doi.org/10.1201/b17208

Pang, S., & Mujumdar, A. S. (2010). Drying of woody biomass for bioenergy: Drying technologies and optimization for an integrated bioenergy plant. *Drying Technology, 28*(5), 690–701. https://doi.org/10.1080/07373931003799236

Pribadi, A. (2020, February 27). *Terapkan metode co-firing di PLTU, ini potensi biomassa untuk substitusi batubara* (Siaran Pers No. 092.Pers/04/SJI/2020). Kementerian Energi dan Sumber Daya Mineral Republik Indonesia. Retrieved April 17, 2023, from https://www.esdm.go.id/id/media-center/arsip-berita/terapkan-metode-co-firing-di-pltu-ini-potensi-biomassa-untuk-subtitusi-batubara

PT PLN (Persero). (2021). *Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) PT PLN (Persero) 2021–2030.* Jakarta: PT PLN (Persero).

PT PLN (Persero). (2022). *Laporan realisasi implementasi co-firing PLTU JAMALI per Mei 2022*. Jakarta: PT PLN (Persero).

Saaty, T. L. (1980). *The analytic hierarchy process: Planning, priority setting, resource allocation.* New York, NY: McGraw-Hill International.

Saaty, T. L., & Vargas, L. G. (2012). *Models, methods, concepts & applications of the analytic hierarchy process* (Vol. 175). In *International Series in Operations Research & Management Science* (Vol. 175). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4614-3597-6

Saltelli, A., Ratto, M., Tarantola, S., & Campolongo, F. (2005). Sensitivity analysis for chemical models. *Chemical Reviews, 105*(7), 2811–2828. https://doi.org/10.1021/cr040659d

Salwa, H. N., Sapuan, S. M., Mastura, M. T., & Zuhri, M. Y. M. (2019). Analytic hierarchy process (AHP)-based materials selection system for natural fiber as reinforcement in biopolymer composites for food packaging. *BioResources, 14*(4), 10014–10036. https://doi.org/10.15376/biores.14.4.10014-10036

Stenström, S. (2017). Drying of biofuels from the forest: A review. *Drying Technology, 35*(10), 1167–1181. https://doi.org/10.1080/07373937.2016.1258571

Tian, G., Zhang, H., Jia, H., Liu, Y., Xu, G., & Wang, J. (2016). Automotive style design assessment and sensitivity analysis using integrated analytic hierarchy process and technique for order preference by similarity to ideal solution. *Advances in Mechanical Engineering, 8*(5), 1–15. https://doi.org/10.1177/1687814016649885

Verma, M., Loha, C., Sinha, A. N., & Chatterjee, P. K. (2017). Drying of biomass for utilising in co-firing with coal and its impact on environment: A review. *Renewable and Sustainable Energy Reviews, 71*, 732–741. https://doi.org/10.1016/j.rser.2016.12.101

Vigants, E., Vigants, G., Veidenbergs, I., Lauka, D., Klavina, K., & Blumberga, D. (2015). Analysis of energy consumption for biomass drying process. *Engineering for Rural Development (ETR), 2*, 317. https://doi.org/10.17770/etr2015vol2.625

Wicaksono, A. (2021). *Studi numerik pengaruh variasi excess air dan jumlah bahan bakar biomassa pada proses co-firing terhadap efisiensi boiler tipe tangensial pulverizer pada PLTU Lontar* [Undergraduate thesis, Institut Teknologi Sepuluh Nopember]. ITS Repository.