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Vertical Axis Wind Turbine as a Miniature Project of Renewable Energy for Indonesia Gold 2045: A Bibliometric and Survey Analysis

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Abstract. This study aims to describe the trends, contributions, and perspectives of students as opportunities for the application of vertical axis wind turbines. This study uses a mixed method design with an explanatory sequential scheme. Data collection techniques were carried out on the Scopus database and through a student survey using a questionnaire. The results show that research with the keywords "vertical axis wind turbine" and "renewable energy" is still trending. The increase in documents each year shows that this research continues to grow. Bibliometric analysis shows that the affiliation that contributes most to research on the keywords "vertical axis wind turbine" and "renewable energy" is the University of Malaya. Other data show that the countries that are productive in researching vertical axis wind turbines and renewable energy are India, Malaysia, and China. The results of the student responses show that they strongly agree with the application of vertical axis wind turbines in Indonesia. This is reinforced by the results of the literature and student responses through interviews that vertical axis wind turbines are suitable for application in urban areas. This study hopes that Indonesia can develop new innovations in the use of renewable energy.

1 Introduction

Technological transformation has an impact on the sustainability of human activities. According to Bamati & Raoofi [1], many technologies have an impact, including the development of renewable energy. It is hoped that this technology will provide Indonesia with the opportunity to become a country that has an impact on renewable energy. In addition, it is hoped that SDG 7 in Indonesia can be realized in accordance with the vision and mission of utilizing renewable energy [2][3].

The fact is that Indonesia has abundant natural resources that can be used as renewable energy sources. Data from the Ministry of Energy and Mineral Resources shows that the Indonesian government is targeting a renewable energy mix of 23% by 2025 [4]. Therefore, contributions are needed to realize this goal in line with the facts.

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Other facts show that the utilization of wind energy in Indonesia is still very minimal, at 1%. According to Amijth & Bavanish [5], utilizing wind energy has great potential in terms of environmental friendliness compared to fossil fuels. In addition, research conducted by Pambudi et al. [6] states that Indonesia has abundant wind energy resources. This fact poses a challenge for Indonesia in utilizing wind energy with adequate technology.

Many assume that windmills are the only technology suitable for harnessing wind energy to generate electricity. In fact, there is a new innovative product that utilizes wind energy sources, namely vertical-axis wind turbine technology. Previous research conducted by Rizki et al. [7] conducted experiments using miniature vertical-axis wind turbines as a renewable energy technology solution. This research has the limitation of being limited to experimentation. There is a need for research mapping and critical responses from academics in addressing the use of vertical-axis wind turbines as a renewable energy solution in Indonesia.

This study offers a bibliometric study of students' perspectives on vertical-axis wind turbines as a renewable energy solution in Indonesia. This perspective is needed because there is a need for an opinion regarding the suitability of the environment to be used as an energy source and how it works so that Indonesia can produce these devices [8][9]. Through this strategy, Indonesia will have support in continuing its renewable energy mission. Therefore, this study aims to describe the issues raised in this study.

RQ1: How is the trend and contribution of research on vertical axis wind turbines as a renewable energy solution?

RQ2: How do students respond to vertical axis wind turbines as a renewable energy solution in Indonesia?

2 Methods

2.1 Research Design

This study uses a mixed method design with an explanatory sequential scheme. Figure 1 shows the research flow.

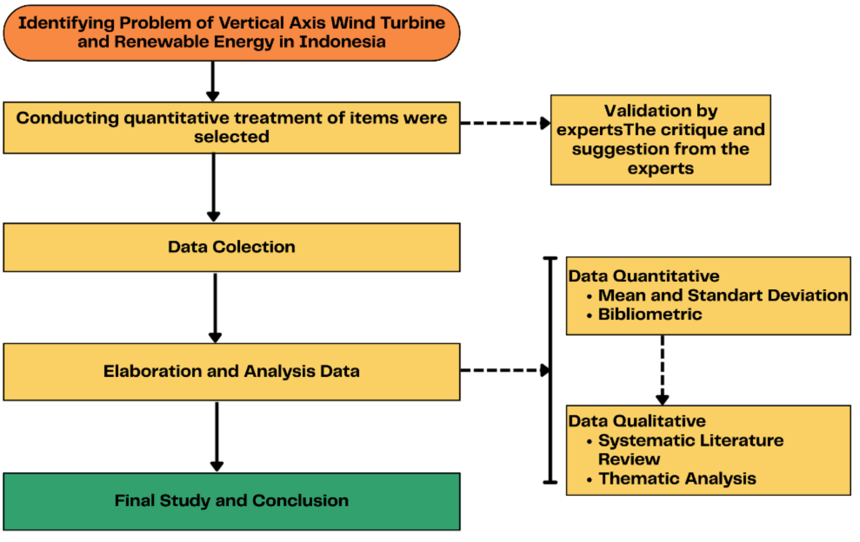


Fig. 1. Research Flowchart

This study consists of five stages in the process. In the first stage, the researcher identifies existing problems in Indonesia. In the second stage, the researcher prepares the research instruments to be used. In the third stage, the researcher collected data through questionnaires distributed to the sample and collected data through the Scopus database. In the fourth stage, the researcher elaborated and analyzed the data using a mixed method of quantitative data reinforced by qualitative data. In the fifth stage, the researcher concluded the results of the research.

2.2 Data Collection Processing

This study used a questionnaire sample given to students. There were several stages in the data collection process for this study. Figure 2 illustrates the stages of the data collection process carried out over a period of one month.

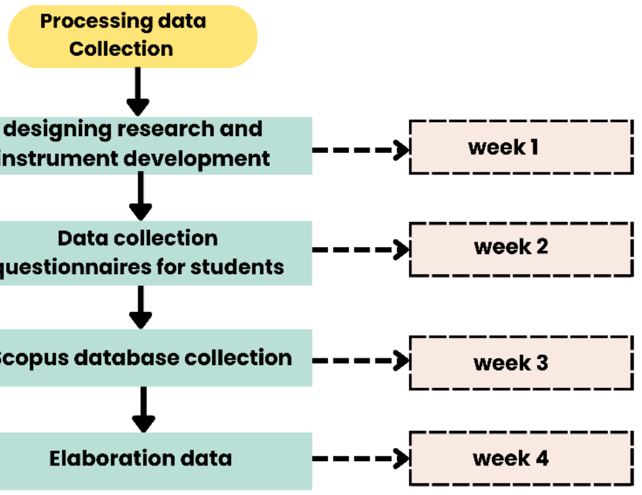


Fig. 2. Data Collection Process

Based on Figure 2, the researchers collected data over a period of four weeks. In the second week, the researchers distributed questionnaires to the sample group. This process was carried out by showing a video study on vertical axis wind turbines. During this process, the sample group watched the video and then provided their responses.

The research sample was given to students at all levels. The data was elaborated into several clusters. Table 1 explains the number of data clusters obtained from each student.

Table 1. Data Clustering

Level of Education	
Bachelor	12
Magister	9
Doctor	9
Gender	
Male	10
Female	20

In addition, there is also PRISMA to obtain bibliometric data stages. These stages begin with identification, screening, and eligibility. Figure 3 is PRISMA obtained from the Scopus database.

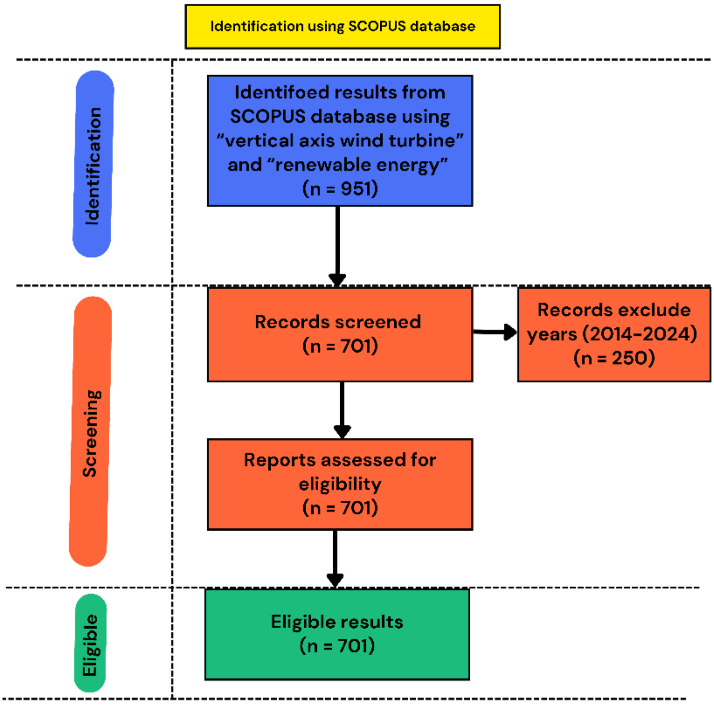


Fig. 3. PRISMA Diagram

2.3 Research Instrument

This study used a Likert scale questionnaire and brief interviews. The Likert scale questionnaire questions are shown in Table 2.

Table 2. Questionnaire Question

No	Question
1	Activities using Horizon's Vertical Axis Wind Turbine Science Kit support understanding of the concept of wind energy as renewable energy (Q1).
2	Horizon's Vertical Axis Wind Turbine Science Kit can help explain the principle of converting wind kinetic energy into electrical energy. (Q2)
3	The components in Horizon's Vertical Axis Wind Turbine Science Kit are easy to assemble and use (Q3).
4	Horizon's Vertical Axis Wind Turbine Science Kit design can motivate students in Indonesia to experiment (Q4)
5	The use of Horizon's Vertical Axis Wind Turbine Science Kit can help physics teachers implement active learning (Q5).
6	The use of Horizon's Vertical Axis Wind Turbine Science Kit has the potential to be used for the evaluation of practice-based learning (Q6).
7	Horizon's Vertical Axis Wind Turbine Science Kit encourages students to think in an interdisciplinary manner (Q7)
8	Experience using Horizon's Vertical Axis Wind Turbine Science Kit in physics education can develop problem-solving skills (Q8).
9	The concepts taught using Horizon's Vertical Axis Wind Turbine Science Kit are relevant to the renewable energy situation in Indonesia (Q9).
10	Through the experience of using Horizon's Vertical Axis Wind Turbine Science Kit, students and university students can be inspired to develop renewable energy technology (Q10).

No	Question
11	Horizon's Vertical Axis Wind Turbine Science Kit can be integrated into physics lessons in Indonesian high schools or universities (Q11).
12	Experimental experience using Horizon's Vertical Axis Wind Turbine Science Kit has the potential to support government programs related to clean energy transition (Q12)

2.4 Data Analysis

Two analysis techniques were used, namely quantitative data and qualitative data obtained from the research. Quantitative data was analyzed first using descriptive quantitative analysis with the mean and standard deviation (SD) methods. Mean analysis was used to describe the differences in responses to the questionnaire distributed. SD analysis was used to describe the variance in student responses to the questionnaire. In addition, quantitative data was obtained through bibliometric analysis using Biblioshinny. Qualitative data was analyzed using descriptive and thematic methods, by reducing the responses of each level of student and elaborating on interesting responses. Furthermore, qualitative data was obtained through a systematic literature review using the Scopus database by selecting open access articles with many citations.

3 Results

3.1 Trending and Research Contributions Vertical Axis Wind Turbine Renewable Energy Solutions

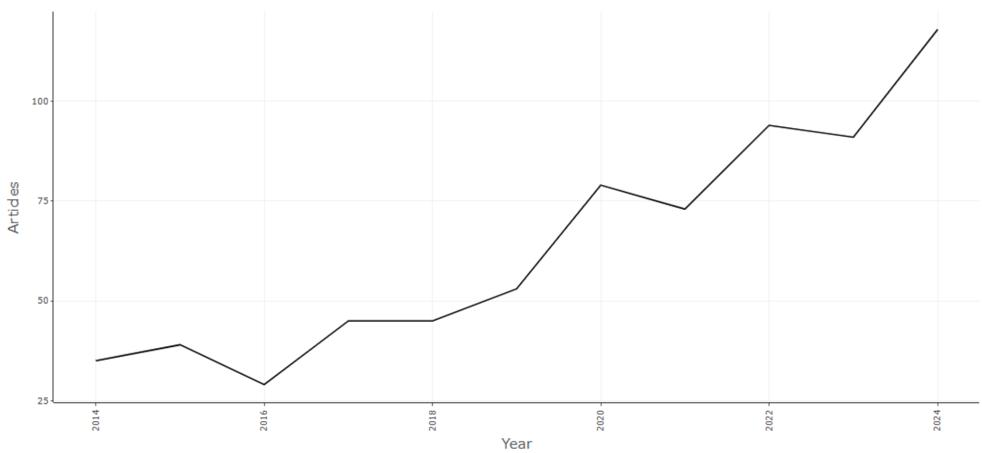


Fig. 4. Publication Overtime Years

The results show that research with the keywords (vertical axis wind turbine AND renewable energy) from 2014 to 2024 has increased. This indicates that research with the keywords (vertical axis wind turbine AND renewable energy) is still very relevant and has a high impact. The increase in results peaked in 2024 with 106 articles using the keywords (vertical axis wind turbine AND renewable energy). The increase in research on (vertical axis wind turbine AND renewable energy) shows the need for renewable energy and its supporting tools for sustainability. Based on these results, the role of renewable energy has a significant impact, so there needs to be research related to (vertical axis wind turbine AND renewable energy) to provide innovation every year and have an impact.

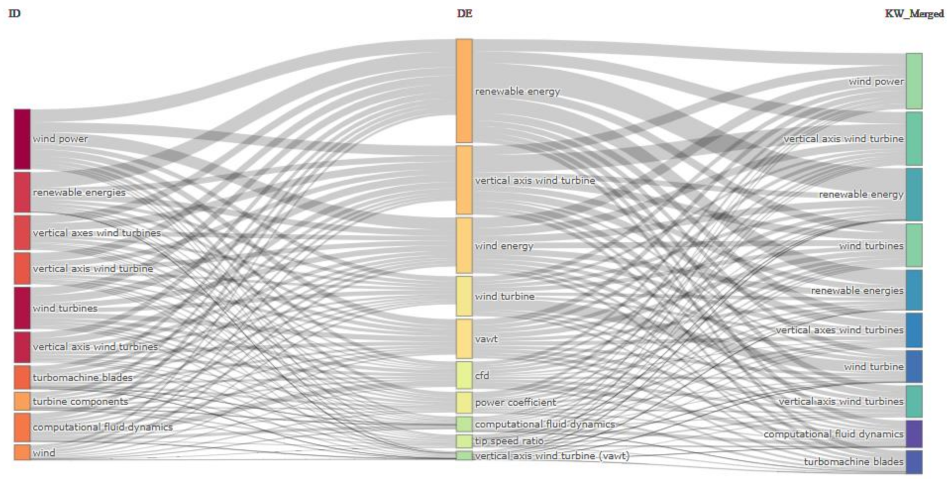


Fig. 5. Three Field Plot

The Figure 5 shows a three-field plot that illustrates the relationship between each keyword obtained from the Scopus database. The three fields used in the relationship are keyword plus, keyword, and all keywords. In this context, it shows that there is a relationship between additional keywords and the main keyword and all keywords. In the context of additional keywords that have many criteria, the keywords are "Renewable Energy," "Wind Power," and "Wind Turbines." These additional keywords are related to the main keywords, namely "Renewable Energy," "Vertical Axis Wind Turbine," and "Wind Energy." This indicates that the Scopus database searched has significant connections in research. Thus, research on renewable energy and wind power is related to vertical axis wind turbines.

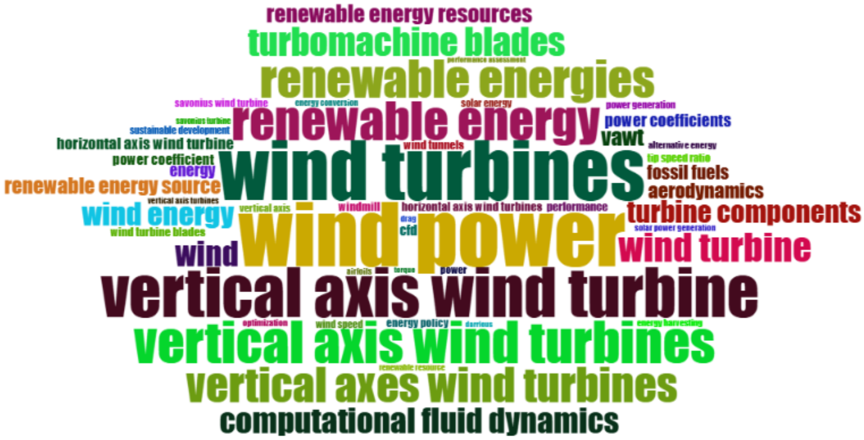


Fig. 6. Wordcloud Keyword

The Figure 6 shows the results of word cloud cluster analysis, which indicates the number of relevant keywords found. The word cloud results show that there are three keywords that dominate the research (vertical axis wind turbine AND renewable energy), namely vertical axis wind turbine, wind power, and wind turbine. This indicates that these three keywords are related to the research (vertical axis wind turbine AND renewable energy), which means they play a role in the research. In addition to the search keywords in the Scopus database, the word “renewable energy” also appears in the word cloud cluster. This shows that renewable energy is related to wind power in vertical axis wind turbines.

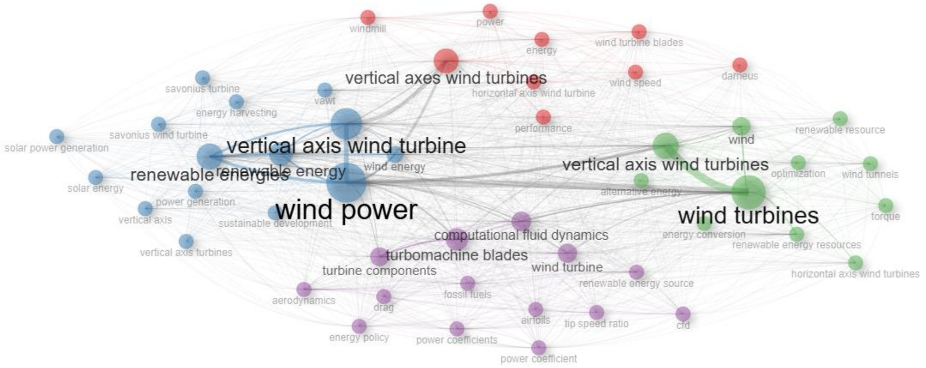


Fig. 7. Co-Occurrence Network

The Figure 7 shows the relationship between keywords differentiated based on research connectivity clusters. The results are divided into three clusters, namely blue and red, green, and purple, each of which has a research focus. The blue cluster has a research focus related to vertical axis wind turbines, which is linked to the keywords wind power and renewable energies. The green cluster focuses on wind power research. This indicates that research on vertical axis wind turbines is related to the mapped clusters, and this connection is fostering a new revolution.

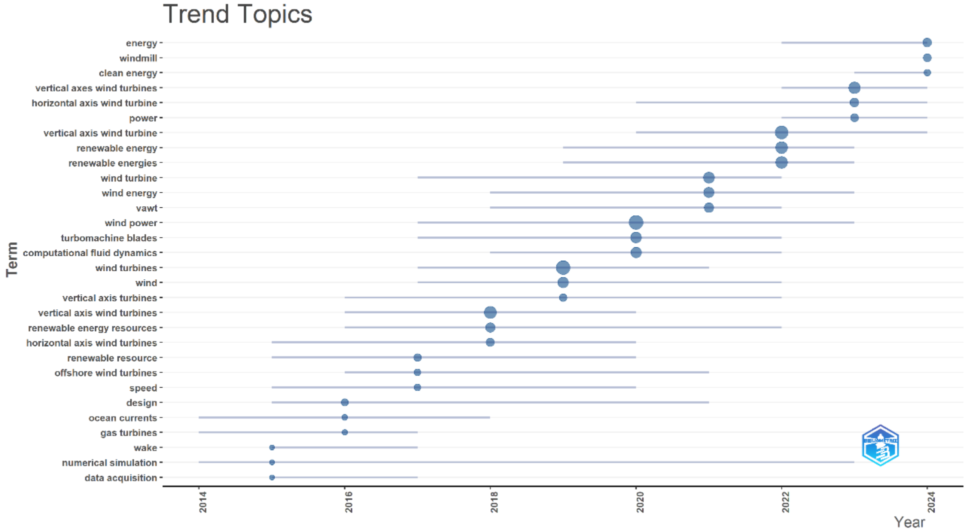


Fig. 8. Trend Topics Overtime Years

The Figure 8 shows that every year there is a trend in research topics related to the keywords (vertical axis wind turbine AND renewable energy). In 2022, the trending research topics discussed were vertical axis wind turbines and renewable energy. This shows that the needs and innovations related to these two keywords are very necessary and have an impact. In that year, global warming occurred, so it was necessary to mitigate the effects of global warming. In 2020, the trending keyword was wind power. In 2020, there was an economic crisis, necessitating solutions to reduce spending and the need to utilize energy that requires minimal funds. By utilizing renewable natural resources, life can continue.

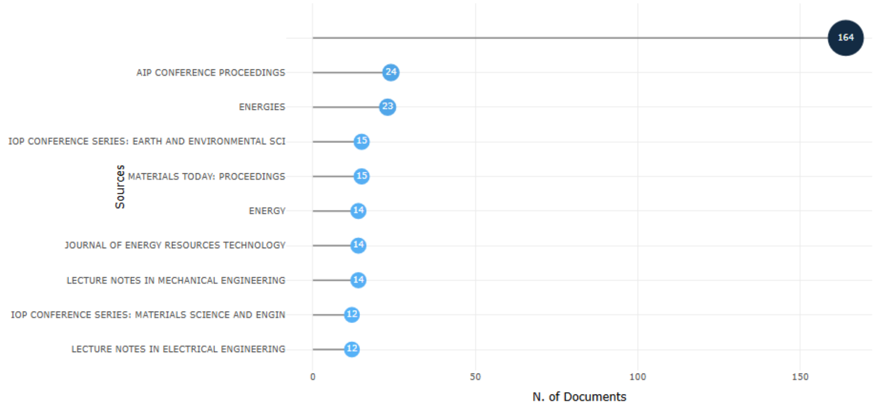


Fig. 9. Top Source Productive

The Figure 9 shows that research related to (vertical axis wind turbine AND renewable energy) can be found in AIP Conference Proceedings. A total of 164 documents were identified in undefined journals, which means that the source of research on (vertical axis wind turbine AND renewable energy) is unknown. The AIP Conference Proceedings has 24 documents, which means that the conference produces a lot of research related to (vertical axis wind turbine AND renewable energy). Meanwhile, the Energies journal has 23 documents, which means that this journal produces a lot of research related to (vertical axis wind turbine AND renewable energy). This indicates that relevant references regarding research on (vertical axis wind turbine AND renewable energy) can be found in the AIP Conference Proceedings and the Energies journal.

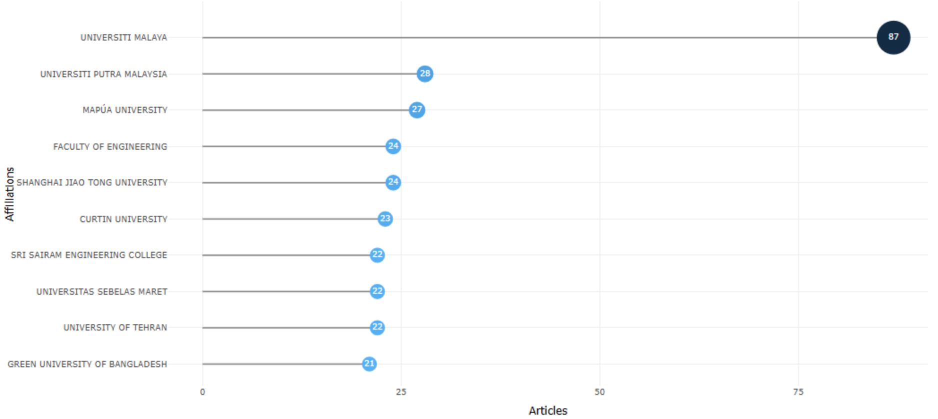


Fig. 10. Top Affiliation Productive

The Figure 10 shows productive affiliations in conducting research (vertical axis wind turbine AND renewable energy). The University of Malaya has published 87 documents on vertical axis wind turbine AND renewable energy research. This indicates that the University of Malaya is highly productive in conducting research on (vertical axis wind turbine AND renewable energy). Therefore, it is recommended to conduct research collaboration related to (vertical axis wind turbine AND renewable energy) with Universiti Malaya. According to Ahmed et al. [10], conducting collaborative research is recommended in order to increase information and new knowledge, so if you want to conduct research related to (vertical axis wind turbine AND renewable energy), you can collaborate with Universiti Malaya. Indonesia has one of the affiliations that contributes significantly to research on vertical axis wind turbines and renewable energy, providing Indonesia with an opportunity to develop new innovations related to vertical axis wind turbines and renewable energy.

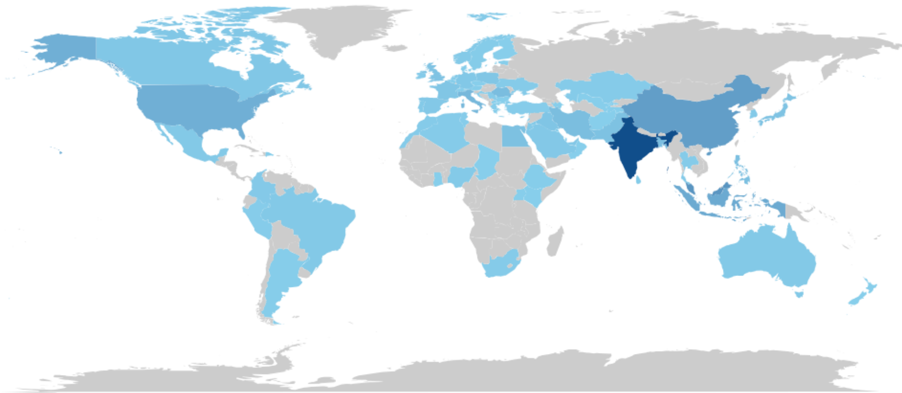


Fig. 11. Top Country Productive

The Figure 11 shows the countries that contribute to research (vertical axis wind turbine AND renewable energy) each year. The distribution of the map shows that India is a productive country in conducting research (vertical axis wind turbine AND renewable energy). This is evidenced by the color of the cluster, which is blue and gradually turning black. Other countries that contribute to research (vertical axis wind turbine AND renewable energy) are Malaysia and China, which show different cluster colors. This indicates that collaboration on research (vertical axis wind turbine AND renewable energy) can be carried out through an international research network with India, Malaysia, and China. In addition, Indonesia has a dark blue cluster, which indicates that research on vertical axis wind turbines and renewable energy is being conducted in Indonesia.

3.2 Student Perspectives on Horizon's Vertical Axis Wind Turbine

Student responses were clustered based on the level of education pursued by the students. The results include the mean and SD values based on the Likert scale. Table 3 shows student responses to Horizon's Vertical Axis Wind Turbine.

Table 3. Response Student

Number Question	Mean			SD		
	Bachelor	Magister	Doctor	Bachelor	Magister	Doctor
1	4.67	4.67	4.78	0.49	0.71	0.44
2	4.67	4.78	4.33	0.49	0.44	0.50
3	4.16	4.44	4.33	0.83	0.72	0.50
4	4.58	4.78	4.55	0.51	0.44	0.52
5	4.67	4.78	4.67	0.49	0.44	0.50
6	4.50	4.78	4.89	0.67	0.50	0.33
7	4.50	4.56	4.56	0.67	0.72	0.52
8	4.41	4.56	4.56	0.66	0.72	0.72
9	4.67	4.44	4.56	0.65	1.01	0.52
10	4.44	4.33	4.56	0.88	1.11	0.52
11	4.58	4.67	4.56	0.51	0.70	0.52
12	4.41	4.56	4.56	0.66	0.72	0.52

Based on the Table 3 shows that the mean score is close to 5, which means that respondents strongly agree with the presence of vertical axis wind turbines in Indonesia. The standard deviation shows the highest score, which means that respondents gave a wide variety of answers to the questions asked. From this data, there is a unique finding, namely that question number 10 has the highest SD value at the master's level, meaning that master's students gave a wide variety of responses to question number 10. This is evidenced by the mean for master's students for question number 10, which has a score of 4.33, meaning that there are respondents who are for and against question number 10. From several responses, students gave many opinions about their agreement with the application of vertical axis wind turbines in Indonesia.

Statement number 10 is "Through the experience of using Horizon's Vertical Axis Wind Turbine Science Kit, it can inspire students or university students to develop renewable energy technology," but respondents R17 and R21 gave statements that disagreed. Respondent R17 disagreed because Indonesia has not yet implemented renewable energy technology (wind-based) to date, so it would be difficult to inspire students or university students. According to respondent R21, Indonesia needs to implement wind energy into electricity in order to inspire the development of renewable energy technology. From these statements, it is clear that Indonesia needs to implement renewable energy technology (wind-based) in order to inspire and develop new innovations in wind-based renewable energy technology.

4 Discussion

Before discussing this further, it is necessary to understand the potential of wind energy as a renewable energy source in Indonesia. Figure 12 [11] shows the percentage of renewable energy sources used in Indonesia.

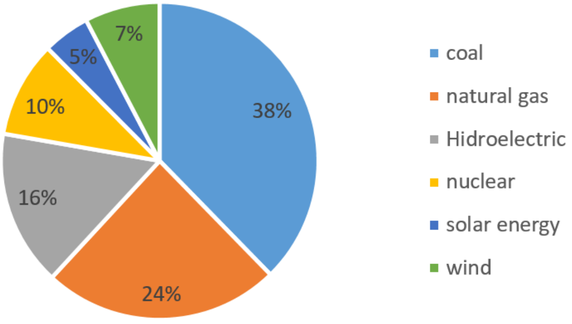


Fig. 12. Percentage of Renewable Energy Utilization in Indonesia

Based on the Figure 12 it shows that the largest use of energy in Indonesia is still coal. This shows that Indonesia still uses non-renewable energy sources for its livelihood. On the other hand, there is a percentage showing that wind energy accounts for 7%, which means that Indonesia utilizes renewable energy for its livelihood. This shows that Indonesia still has opportunities to utilize wind energy, so there is a need for innovation in utilizing wind energy for its livelihood. Therefore, this study will discuss the opportunities for innovation in utilizing wind energy for livelihood.

4.1 Trending and Research Contributions Vertical Axis Wind Turbine Renewable Energy Solutions

The bibliometric data results in Figures 4 to 11 will be reinforced by a systematic literature review on the importance of research on vertical axis wind turbine renewable energy solutions. Table 4 is a systematic literature review to reinforce the trending data results and research contributions.

Table 4. Systematic Literature Review

Identity	Results Research	Recommendation	Strengths	Weakness	*Ct
Roga et al. [12]	Wind turbines are classified into Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT). HAWTs are more efficient for large-scale applications, while VAWTs are suitable for urban areas due to their ability to capture wind from all directions and produce less noise.	This article provides suggestions for further research, namely the development of AWE and the optimization of hybrid systems for renewable wind energy.	The article covers almost all aspects of modern wind energy technology, from basic structures to the latest innovations such as AWE and MagLev.	The article tends to be descriptive without critically highlighting the significant weaknesses of each technology, especially in terms of cost and environmental impact.	249
Wenehenubun et al. [13]	This study conducted an experimental study to analyze the effect of the number of blades (2, 3, and 4 blades) on the performance of Savonius wind turbines. The experiment was conducted in a wind tunnel with wind speeds varying from 1 to 10 m/s, and was equipped with pressure distribution simulation using ANSYS 13.0. The 3-bladed turbine is most optimal for applications that require high rotational speed and efficiency, while the 4-bladed turbine is suitable for applications that require high initial torque at low speeds.	This research proposes field testing with a full-scale prototype to validate laboratory experimental results through transient simulation or turbulent flow analysis to understand the phenomena of flow separation and vorticity.	The advantages of a clear methodological article with controlled variables (number of blades, wind speed) enable direct comparative analysis. In addition, the integration of experimental data (torque, TSR) and ANSYS simulation provides a comprehensive understanding of pressure distribution.	This study has limitations in terms of the scope of parameters and testing conditions, thus opening up opportunities for further studies with more complex variables and conditions that are closer to real-world applications.	202

Identity	Results Research	Recommendation	Strengths	Weakness	*Ct
Kwok & Hu [14]	Various innovative systems are described, such as Vertical Axis Wind Turbines (VAWT), Power Windows (linear cascade turbines), and wind-induced vibration-based energy harvesters (utilizing the phenomena of VIV, galloping, and flutter). These systems are more suitable for urban environments due to their ability to operate at low wind speeds and high turbulence.	This study suggests that the use of hybrid (wind-solar) and multi-rotor systems can be explored to improve energy efficiency. In addition, further validation of AI and ML models in real-world contexts is needed, including the application of sensor placement optimization algorithms on a city scale.	The article covers almost all aspects related to urban wind energy, ranging from aerodynamics, building design, case studies, to the latest technologies such as AI and ML.	The article is a review and therefore does not present new data analysis or original modeling.	80
Shamsoddin & Porté-Agel [15]	The author conducted 117 LES-ALM simulations to analyze the effect of tip-speed ratio (TSR) and chord length on the power coefficient (CPCP). The optimal combination was found at TSR = 4.5 and solidity Nc/R=0.18Nc/R=0.18, resulting in a maximum CPCP of 0.47 (equivalent to 1.3 MW of power).	Research on the placement and configuration of turbines in VAWT wind farms to minimize wake interaction and maximize efficiency.	The study covers performance optimization and detailed wake analysis, including turbulent statistics that are rarely discussed in VAWT literature.	The accuracy of the results depends heavily on the MIT model used, which may not fully represent the dynamic stall phenomenon under all conditions.	73

*Ct: Citation

The results of the Table 4 provide the essence of the literature review, which states that vertical axis wind turbines are very suitable as an alternative for utilizing wind energy for sustainability. From four literature reviews with the top keyword citations (vertical axis wind turbine AND renewable energy), there has been continuous development in efforts to utilize renewable energy. Furthermore, according to Roga et al. [12], vertical axis wind turbines are suitable for use in urban areas. The characteristics of urban areas that can be used as a reference are as follows: (1) high population density, (2) developed infrastructure, and (3) non-agricultural economic activities. This significantly indicates that vertical axis wind turbines can be applied in Indonesia, which has many urban areas.

4.2 Student Perspectives on Horizon's Vertical Axis Wind Turbine

To reinforce the results of the Table answers 4, the researchers conducted interviews as supporting data for the study. The interview data results were modeled through thematic concept maps based on the students' perspectives. Furthermore, before further discussion, it is necessary to understand the definition of a vertical axis wind turbine. The descriptive results of the interviews can be represented as shown in Figure 13 thematic definition of a vertical axis wind turbine.

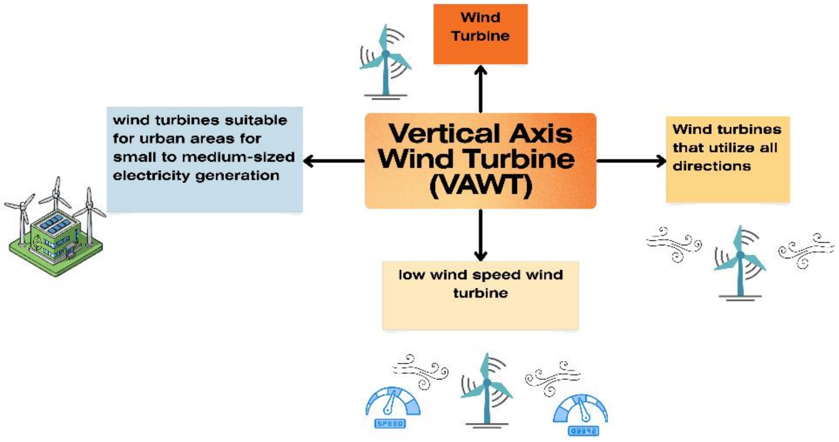
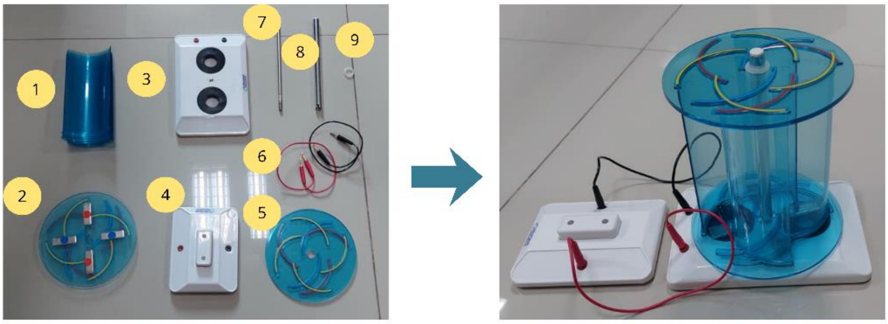


Fig. 13. Thematic Description of VAWT

Based on Figure 13, it can be seen that VAWT is a wind turbine that utilizes wind from all directions, even at low wind speeds. VAWT is suitable for use in urban areas and areas that require small or medium amounts of electricity. This shows that VAWTs have the potential to be implemented in Indonesia, as proven by the students' perspective. VAWTs are an innovative product for utilizing wind energy. According to Amijth & Bavanish [5], utilizing wind energy has great potential in terms of environmental friendliness compared to fossil fuels. To clarify the shape of a VAWT, a small miniature is presented in Figure 14.



1. 4 Blades
2. Lower Blade Plate and 4 Magnets
3. 1 Wind Turbine Base
4. 1 LED Base
5. Upper Blade Plate
6. Red and Black Wire
7. 1 Aluminium Rod
8. 1 Stainless steel rod
9. Balde Plate Lock

Fig. 14. Miniature of VAWT

The Figure 14 illustrates the miniature VAWT and its components. Based on the students' perception, the VAWT works by rotating due to wind from all directions, converting mechanical energy into electrical energy. Through this miniature project, it is hoped that future generations will be able to implement VAWTs on a large scale. Step by step, through learning and development, VAWT has gained support for implementation in Indonesia. In this way, coal utilization can be reduced through VAWT innovation as a means of sustainability. This research hopes to contribute through students' perceptions as a driving force to support VAWT development through learning among students and the community.

5 Conclusion

This study concludes that research related to vertical axis wind turbines and renewable energy has remained a trend over the past 10 years. This is evidenced by the increase in the number of researches documents each year. In addition, the keywords “vertical axis wind turbines” and “renewable energy” always appear in bibliometric analysis. The affiliation that contributes most to research related to the keywords “vertical axis wind turbines” and “renewable energy” is the University of Malaya. Other data show that the countries that are productive in research on vertical axis wind turbines and renewable energy are India, Malaysia, and China. The results obtained show that research related to vertical axis wind turbines and renewable energy still needs to be developed for sustainability. Responses from student respondents show a high level of agreement and provide a lot of variety regarding the development of vertical axis wind turbines in Indonesia. These responses are reinforced by student responses that refer to areas where vertical axis wind turbines can be applied in Indonesia through interviews. These responses can be an opportunity for Indonesia to develop vertical axis wind turbines. This study hopes that Indonesia can develop new innovations in the use of renewable energy. This study is limited to the results of student respondents whose number is still small. In addition, the bibliometric limitation of the database used is only the last 10 years, so there needs to be an expansion of the bibliometric analysis. Further research is recommended to expand the scale of research on application and bibliometric. This aims to develop further research and innovation.

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References

1. Bamati N and Raoofi, A Renew. Energy **151** 946–55 (2020).
2. Kibtiah T M, Dewi G D P, Bainus A, Abdurrahman M F, RHasan D and Suitela K M IOP Conf. Ser.: Earth Environ. Sci. **1324** 012093 (2024).
3. Santika W G, Urmee T, Simsek Y, Bahri P A and Anisuzzaman M. Energy for Sustainable Development **59** 33–48 (2020).
4. Kementerian Energi dan Sumber Daya Mineral Republik Indonesia 2024 *Ini besaran alokasi subsidi energi di tahun 2025* (Accessed: 28 August 2024) https://www.esdm.go.id/id/media-center/arsip-berita/ini-besaran-alokasi-subsidi-energi-di-tahun-2025
5. Amjith L R and Bavanish B. Chemosphere **293** 133579 (2022)

6. Pambudi N A, Ulfa D K, Nanda I R, Gandidi I M, Wiyono A, Biddinika M K, Rudiyanto B and Saw L H Sustainability **17** 1312 (2025)
7. Rizki I A, Suprapto N and Hariyono E. TEM Journal **12**(1) 452 (2023)
8. Langer J, Quist J and Blok K. Energies **14** 7033 (2021)
9. Long A, Lasimbang A, Ahmed M F and Mokhtar M B. E3S Web of Conferences **624** 04001 (2025)
10. Ahmed S, Ali A and D'angola A. Sustainability **16** 1749 (2024)
11. IDXChannel 2021 *Sumber listrik dunia, ternyata batu bara masih jawara* (Accessed: 29 November 2021) https://www.idxchannel.com/economics/sumber-listrik-dunia-ternyata-batu-bara-masih-jawara
12. Roga S, Bardhan S, Kumar Y and Dubey S K. Sustainable Energy Technologies and Assessments **52** 102239 (2022)
13. Wenehenubun F, Saputra A and Sutanto H. Energy Procedia **68** 297–304 2015
14. Kwok K C S and Hu G. Journal of Wind Engineering and Industrial Aerodynamics **234** 105349 (2023)
15. Shamsoddin S and Porté-Agel F. Energies **9**(5) 366 2016