

Bibliometric Analysis of Bioenergy Conversion Technologies: Research Trends, Knowledge Maps, and Future Prospects.

Nasrullah Hamja^{1*}, Ikhsan Hidayat², and Jumiati Ilham³

Graduate School of Renewable Energy, Darma Persada University, Indonesia¹

Computer Engineering, Universitas Negeri Gorontalo, Indonesia²

Electrical Engineering, Universitas Negeri Gorontalo, Indonesia³

*Corresponding Author Email: nasrullahpanasonic.nh@gmail.com

Abstract -- Bioenergy conversion technology plays a crucial role in addressing global energy challenges by converting biomass into usable energy, such as electricity, heat, and biofuels. Although the volume of research in this field continues to grow rapidly, a comprehensive analysis of trends, knowledge structure, and contributions of key actors is still scarce. Through a bibliometric analysis utilizing data from scientific databases, this study reveals publication patterns, journals, and influential contributors, including authors, institutions, and countries. Furthermore, this study maps the H-index, generates a word cloud to identify core themes, and explores the thematic structure and emerging research areas. Further analysis was conducted using a three-field plot based on keywords, publication sources, and country of origin to understand research dynamics. These findings offer crucial insights into the evolution of bioenergy research, identify knowledge gaps, and open opportunities for cross-disciplinary collaboration to drive innovation and support global sustainability.

Copyright © 2025 IJEmCE. All rights reserved.

DOI: 10.xxxxx/ijemce.v1i1.xxxxx

Keywords:

Bioenergy conversion technology,
Sustainable bioenergy,
Bioenergy bibliometric analysis,
H-index in bioenergy research,
Renewable energy and bioenergy

Article History:

Received: October 7, 2025

Revised: October 7, 2025

Accepted: October 8, 2025

Published: October 8, 2025

I. INTRODUCTION

A. Background

The increasing demand for sustainable energy sources has spurred significant attention toward bioenergy conversion technologies [1,2]. These technologies function to convert biomass into usable forms of energy, such as electricity, heat, and biofuels, which are essential in facing global energy challenges. Bioenergy is recognized as a renewable and environmentally friendly energy source, thereby contributing to the reduction of greenhouse gas emissions and climate change mitigation [3]. Rapid advancements in bioenergy conversion technology, from biochemical to thermochemical processes, have resulted in extensive academic and industrial research. However, a systematic analysis is needed to understand the trends, main focuses, and future opportunities of this continuously evolving knowledge.

Bibliometric analysis, as a quantitative approach to reviewing academic literature, offers an effective tool for mapping the research landscape of bioenergy conversion technology [4]. By analyzing publication trends, citation networks, and major contributions, bibliometric studies provide insights into the evolution of this field and help identify knowledge gaps. This analysis is crucial for guiding future research, driving innovation, and aligning scientific efforts with global energy sustainability goals [5].

B. Rumusan Masalah

Although research on bioenergy conversion technology continues to grow rapidly, there is still a lack of comprehensive understanding regarding the main trends, knowledge structure, and future direction in this field. Researchers and policymakers often face challenges in identifying the most influential studies, key contributors, and core thematic areas. This lack of insight can lead to fragmented research efforts, duplication of work, and missed opportunities for cross-disciplinary collaboration [6].

To address these challenges, a bibliometric analysis is required to systematically review the existing literature on bioenergy conversion technology. This study aims to provide a comprehensive overview of the field, reveal important research themes, and propose directions for future exploration. Thus, this research aims to bridge the gap between existing knowledge and the urgent need for innovative bioenergy solutions [7].

C. Research Objectives

This study aims to conduct a bibliometric analysis of bioenergy conversion technology with the following objectives:

- Identify publication trends and patterns in bioenergy conversion technology research over time.
- Identify leading journals that have published research in this field.
- Analyze the most influential authors, institutions, and countries in this domain.
- Map the H-index and Word Cloud of published journals.
- Map the thematic structure of research, including core topics and emerging areas.
- Conduct a three-field plot analysis based on keywords, sources, and countries.

This study focuses on peer-reviewed articles, conference proceedings, and reviews published in reputable journals and databases. The analysis encompasses research on various bioenergy conversion technologies, including biochemical methods (e.g., fermentation, anaerobic digestion), thermochemical methods (e.g., pyrolysis, gasification), and hybrid approaches. Using bibliometric tools and software, this study evaluates key metrics such as citation counts, keyword occurrences, and collaboration networks. The scope of the research is global, reflecting the international nature of bioenergy research and its implications for sustainable development [8].

II. METHOD

A quantitative research approach was employed, using keywords such as bioenergy, energy conversion, and technology as the foundational aspects of the study [9]. A detailed PRISMA method was applied, as illustrated in Figure 1, to ensure a structured and systematic data screening process aligned with the keywords. This approach ensures scientifically valid and high-quality results while assessing the influence of the journals. Bibliometrics was deemed a suitable instrument for this purpose [10].

In addition to providing a comprehensive overview of the intellectual, conceptual, and social framework of the subject, the methodology used in this paper enhances the relevance of the research. Furthermore, this study employs a systematic literature review combined with bibliometric analysis to present quantitative data from various journal articles discussing the use of renewable energy in the context of bioenergy [1,11–13].

The systematic literature review conducted in this study aims to identify research related to biomass, bioenergy, technology, and energy conversion from Scopus databases. The retrieved data were then processed using bibliometric analysis with the assistance of R Studio's Biblioshiny application, which enables researchers to map and visualize topics and subtopics related to bioenergy challenges, technology, and energy conversion. The articles analyzed in this review were obtained from the Scopus database, allowing for analysis using the Bibliometrix and Biblioshiny packages [14]. These databases enable the extraction of bibliographic metadata, including authors, keywords, publication year, article sources, main topics reviewed, key findings, and citations, as well as impact metrics such as H-index, word clouds, thematic maps, and three-field plots [15].

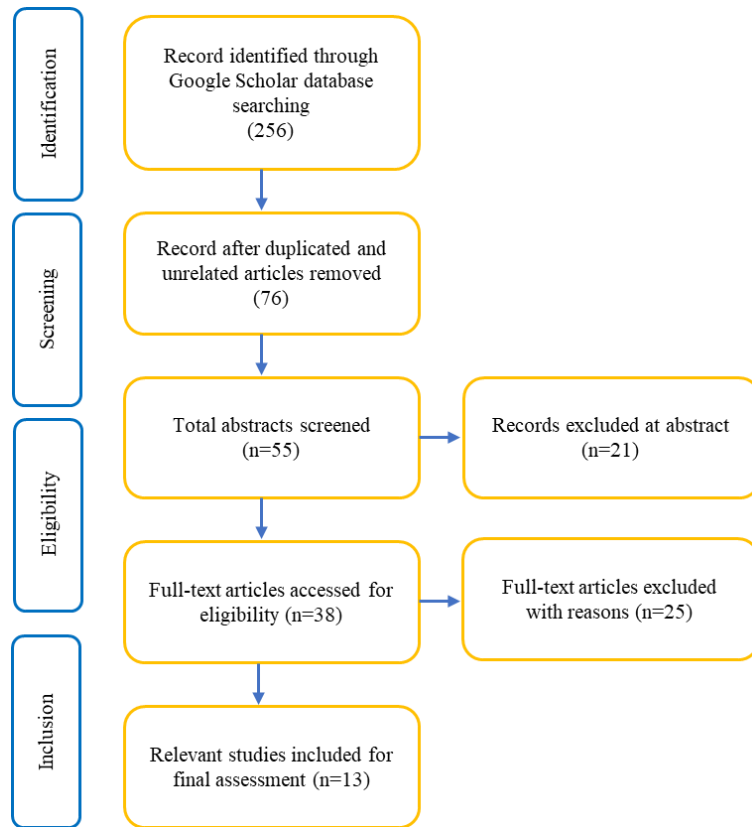


Figure 1. PRISMA Flowchart for Literature Search and Data Extraction

III. RESULT AND DISCUSSION

A. Literature Search Result

The increasing global discussion on bioenergy is illustrated in Figure 2, which shows the total number of articles collected from 2019 to 2024 using the keywords Bioenergy, Technology, and Energy Conversion [1,12,16]. The graph indicates that 2021 saw the highest number of publications, followed by a decline in 2022 and a gradual increase in 2023 and 2024 [17].

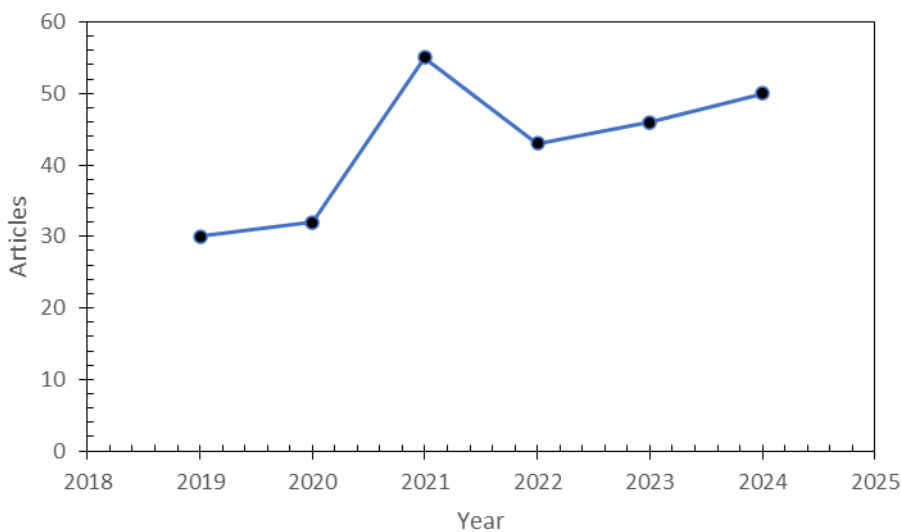


Figure 2. Published Articles

The journals focusing on energy conversion are presented in Figure 3. The collection of journals publishing articles on bioenergy, technology, and conversion [18] shows that the journal *Energies* published the most articles, with 15 documents. This was followed by *Sustainability* and *Biomass and Bioenergy*, which were also major sources with over 8 documents each. Other journals such as *Heliyon*, *Journal of Cleaner Production*, and *Biomass Conversion and Biorefinery* also contributed a number of articles, though fewer than the top three. Other sources like *Journal of Physics: Conference Series*, *Catalysts*, *Energy Reports*, and *Fuel* had smaller contributions but remained relevant to the research topic.

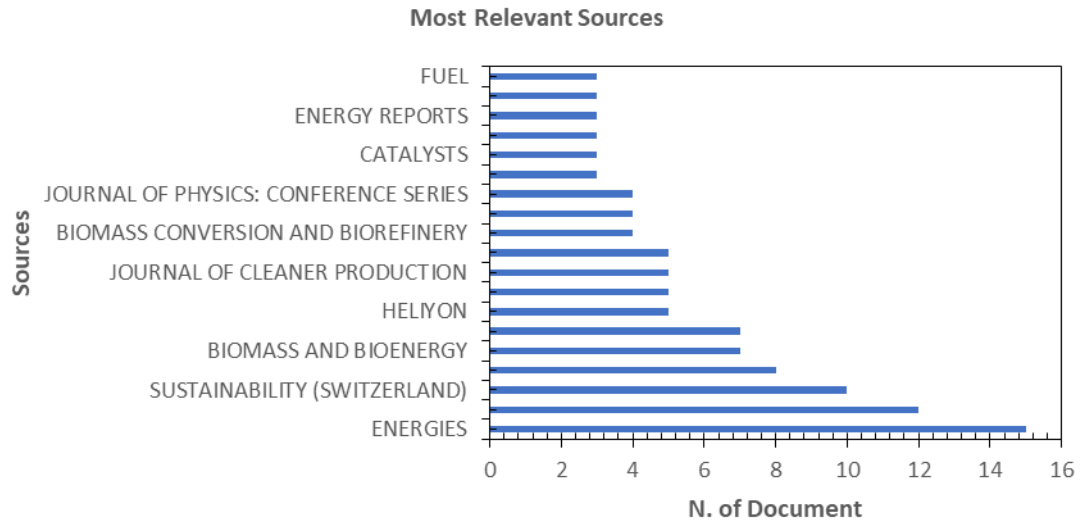


Figure 3. Journal Sources

A review of the collected journals was conducted to identify key findings, along with publication years and total citations, as explained in Table 1. The table provides an overview of journals analyzed from 2019 to 2024 using the keywords bioenergy, technology, and conversion. The collected articles were reviewed based on their main topics and abstracts to identify key research points, along with publication years and citation counts [4,9,19].

TABLE I.
Review of Article Main Topics and Important Findings

Article Review Code	Review Main Topic	Publication Year	Total Citation	Important Findings
[20]	Analysis of the impact of technology in bioenergy processing	2021	36	Optimization of BMW to calculate categories and indicators for consistent and reliable comparisons. The highest positive impact was achieved using fermentation and anaerobic digestion systems.
[21]	Bioenergy technology for agricultural residues using a Pythagorean fuzzy discrimination-based approximation approach	2021	29	Conversion of agricultural residues (ARs) into energy supports regional energy development, agricultural sector growth, and environmental sustainability. A Pythagorean fuzzy set combined with the weighted discrimination-based approximation (WDBA) method was used to select ARs conversion technologies.
[22]	Utilization of coffee waste using ultrasonic technology	2020	25	Exploration of coffee waste as a source of oil for biodiesel production, diverting it from municipal waste to energy. Ultrasonic and Soxhlet extraction methods were used to optimize oil yield from waste coffee grounds (WCG).
[23]	Thermochemical processes for producing bioenergy and biofuels from biomass	2022	15	Conversion of biomass into bioenergy and various biofuels through thermochemical processes, including dry processes (torrefaction, combustion, gasification, pyrolysis) and wet processes (liquefaction, supercritical water gasification, hydrothermal carbonization).
[24]	Providing a resource catalog of biomass, conversion technologies, and SQL-based data	2024	1	Consistently and comprehensively provides information for bioenergy analysis, integrating datasets on 141 raw materials, 259 conversion technologies, and 134 energy supply concepts. The BENOPT model was used to simulate technologies in electricity, heat, and

				transportation sectors.
[25]	A research perspective on integrated bioenergy-based technologies	2019	1	Conversion methods such as direct combustion, anaerobic digestion, fermentation, oil extraction, transesterification, pyrolysis, and gasification to produce bioenergy, biofuels, and biodiesel from biomass.
[26]	A critical review of integrating waste into bioenergy conversion systems	2022	23	Enhancing profitability in waste management systems for biofuel production while reducing greenhouse gas emissions. Classification of biomass waste to match appropriate conversion methods, leveraging synergies between raw materials, processes, and by-products.
[27]	Potential and conversion of biomass and bioenergy	2023	8	Potential of agricultural biomass to generate electricity and biofuels. Discussion of effective policies and strategies for biomass utilization, along with challenges in decentralized waste separation for biomass conversion.
[28]	Bioenergy conversion utilizing agricultural waste for environmentally friendly approaches	2024	3	Biochemical and thermochemical technologies used to convert agricultural waste into bioenergy (e.g., biogas, bio-oil, biofuels) as a solution to meet energy demands while providing environmental benefits and reducing greenhouse gas emissions.
[5]	A comprehensive review of sustainable biofuel and bioenergy production from biomass waste using microwave technology	2021	229	Use of microwave (MW) heating technology in processing biomass waste to produce biofuels and bioenergy. Discussion of challenges in processing raw materials with electromagnetic microwave fields.
[29]	A review of AI-based applications for bioenergy systems	2021	71	Use of AI technology to predict biomass properties and optimize conversion processes. AI-generated data facilitates improved biomass conversion models and biofuel end-use applications.
[30]	Utilization of biomass in bioenergy decarbonization for chemical looping and pacification	2024	9	Information on bioenergy technology with carbon capture and storage for biomass production. Reduction of greenhouse gases through chemical looping processes to enhance biomass conversion efficiency.

Figure 4 illustrates the journals with the highest H-index [31]. Based on the collected data, *Energies* has the highest H-index of 9, followed by *GCB Bioenergy* and *Renewable and Sustainable Energy Reviews* with H-indices of approximately 8 and 7, respectively. Other journals such as *Sustainability*, *Biomass and Bioenergy*, and *Frontiers in Energy Research* also have relatively high H-indices, ranging from 5 to 6, indicating significant influence despite being lower than the top journals. In contrast, *Bioresource Technology*, *Applied Energy*, and *Nature Communications* have relatively lower influence or less direct relevance to the field of bioenergy and conversion [32,33].

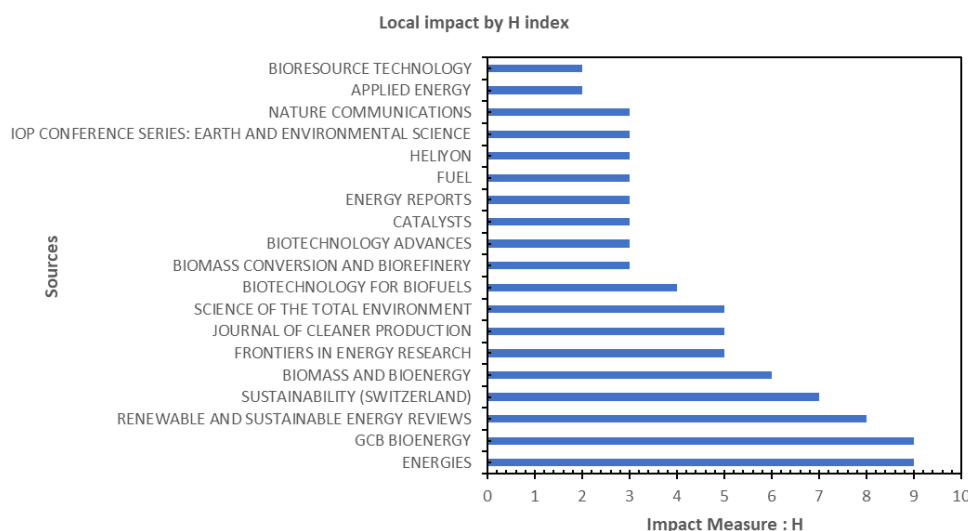


Figure 4. H-index Impact

The productivity and scientific impact of researchers or research groups, measured by publication counts and citations received, are explained in Figure 5. This figure provides information on the most frequently occurring keywords in the collected articles related to *Bioenergy*, *Technology*, and *Conversion* [34,35]. The

A data visualization commonly used in bibliometric analysis to map relationships between three key elements or dimensions in a dataset [40–42] is presented in Figure 7. This figure provides a comprehensive mapping of global bioenergy research, showing the interconnections between research topics, source journals, and countries. The left segment depicts main research areas, including bioethanol fermentation, bioenergy, anaerobic digestion, biofuels, biogas production, pyrolysis processes, gasification, biomass, and circular economy frameworks in the context of renewable energy. The middle segment identifies leading scientific journals in the field, such as *Energies*, *GCB Bioenergy*, *Renewable Energy*, and *Bio-technology*. The right segment highlights countries actively researching the analyzed topics. This analysis offers insights into current research status and identifies patterns to develop solutions for sustainable energy, particularly in bioenergy, technology, and conversion [12,16,28,39,43].

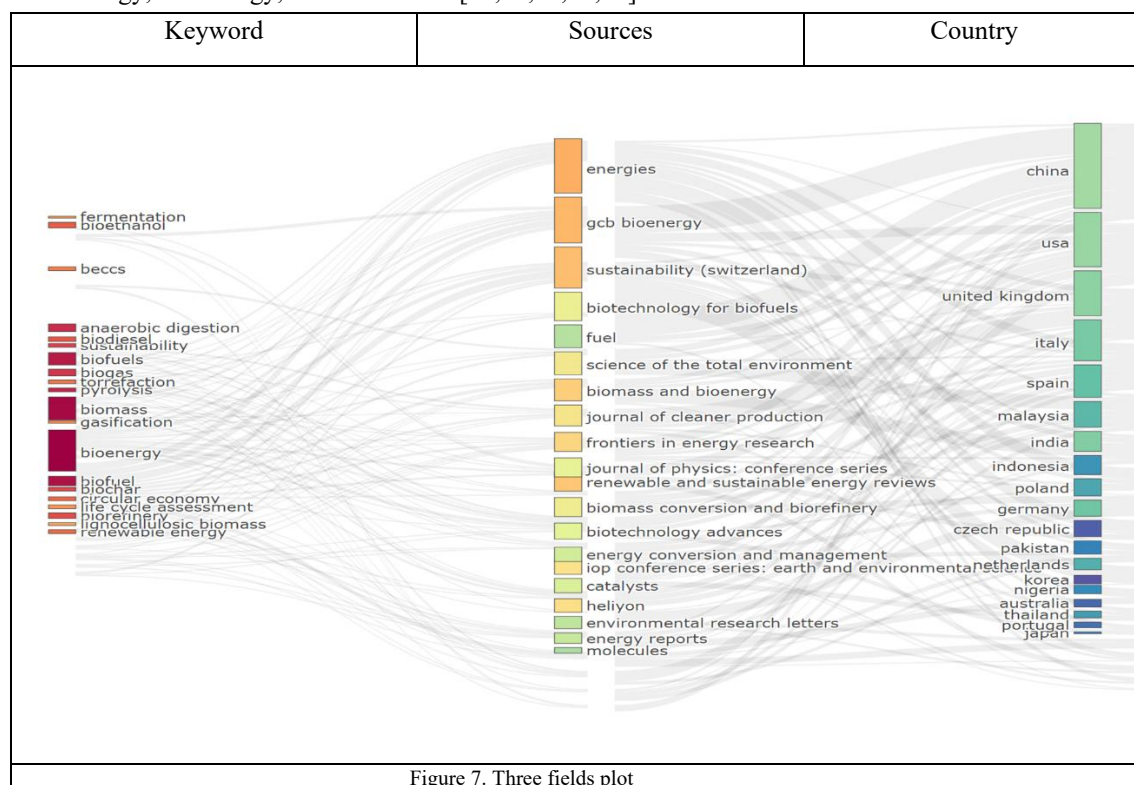


Figure 7. Three fields plot

Bioenergy conversion technology has various potential applications, from electricity generation to environmentally friendly fuel production, supporting the transition to a low-carbon economy [44–46]. Research contributions in this field have enabled the development of more efficient and sustainable methods, such as optimized biomass conversion and integrated hybrid technologies to enhance energy output. However, challenges remain, including improving technology efficiency, reducing production costs, and minimizing environmental impacts of conversion processes [47,48]. Future research should focus on developing new technologies, such as enzyme or microorganism-based bioenergy [49,50], exploring non-conventional raw materials, and applying artificial intelligence to optimize processes. Additionally, further studies on the socio-economic impacts and public acceptance of bioenergy are crucial to ensure widespread and sustainable adoption.

IV. CONCLUSION

The main findings of this study on bioenergy conversion technology are summarized as follows [23,51,52]. The bibliometric analysis successfully identified publication patterns, leading journals, and key contributors in the field of bioenergy [53,54]. The study revealed an increasing trend in bioenergy-related publications over time, with several journals standing out as major sources in this domain. Additionally, the analysis highlighted institutions and countries with significant contributions to bioenergy research, emphasizing the importance of global collaboration in advancing this technology.

This study also mapped the H-index of the analyzed literature, generated a word cloud to identify core

themes, and explored the thematic structure of research, including core topics and emerging areas. The three-field plot analysis based on keywords, publication sources, and countries provided further insights into the relationships between research themes and involved actors.

The results of this study not only offer a deeper understanding of the evolution of bioenergy research but also help identify knowledge gaps for future studies. Thus, this chapter concludes that bioenergy conversion technology has significant potential to support global sustainability, with coordinated and collaborative research being key to optimizing innovation in this field.

V. REFERENCES

- [1] Reid W V., Ali MK, Field CB. *The future of bioenergy*. *Glob Chang Biol* 2020;26:274–86. <https://doi.org/10.1111/gcb.14883>.
- [2] Alkuma YM, Hermawan H, Hadiyanto H. *Pengembangan Potensi Energi Alternatif Dengan Pemanfaatan Limbah Cair Kelapa Sawit Sebagai Sumber Energi Baru Terbarukan Di Kabupaten Kotawaringin Timur*. *J Ilmu Lingkung* 2016;14:96. <https://doi.org/10.14710/jil.14.2.96-102>.
- [3] Rusolono T, Asycarya D, Lindboe HH. *Biomass for Energy Prefeasibility Study*. *Danida Enviromental Support Program* 2018:1–93.
- [4] I RCP, Harahap I, Nawawi Z, Akmal S-R. *Systematic literature review (SLR): transformasi sektor pertanian bagi pembangunan ekonomi di pedesaan Indonesia* 2024;19:16–33.
- [5] Arpia AA, Chen WH, Lam SS, Rousset P, de Luna MDG. *Sustainable biofuel and bioenergy production from biomass waste residues using microwave-assisted heating: A comprehensive review*. *Chem Eng J* 2021;403:126233. <https://doi.org/10.1016/j.cej.2020.126233>.
- [6] Guo M, Song W, Buhain J. *Bioenergy and biofuels: History, status, and perspective*. *Renew Sustain Energy Rev* 2015;42:712–25. <https://doi.org/10.1016/j.rser.2014.10.013>.
- [7] Gírio F. *Innovation on bioenergy*. Elsevier Inc.; 2018. <https://doi.org/10.1016/B978-0-12-813056-8.00009-1>.
- [8] Busu M. *Assessment of the impact of bioenergy on sustainable economic development*. *Energies* 2019;12:1–11. <https://doi.org/10.3390/en12040578>.
- [9] Marzi G, Balzano M, Caputo A, Pellegrini MM. *Guidelines for Bibliometric-Systematic Literature Reviews: 10 steps to combine analysis, synthesis and theory development*. *Int J Manag Rev* 2024:1–23. <https://doi.org/10.1111/ijmr.12381>.
- [10] Mardiantiningsih S, Supported B. *Supported Technology on STEM-Based Science Learning : A Systematic Literature Review To cite this article : Supported Technology on STEM-Based Science Learning : A Systematic Literature Review* 2024.
- [11] Ranta T, Laihanen M, Karhunen A. *Development of the Bioenergy as a Part of Renewable Energy in the Nordic Countries: A Comparative Analysis*. *J Sustain Bioenergy Syst* 2020;10:92–112. <https://doi.org/10.4236/jsbs.2020.103008>.
- [12] Lee SY, Sankaran R, Chew KW, Tan CH, Krishnamoorthy R, Chu D-T, et al. *Waste to bioenergy: a review on the recent conversion technologies*. *BMC Energy* 2019;1:1–22. <https://doi.org/10.1186/s42500-019-0004-7>.
- [13] Welfle A, Thornley P, Röder M. *A review of the role of bioenergy modelling in renewable energy research & policy development*. *Biomass and Bioenergy* 2020;136. <https://doi.org/10.1016/j.biombioe.2020.105542>.

-
- [14] Journal M. *Guidelines for Bibliometric-Systematic Literature Reviews - Teaching & Learning Guide* 2024;1–15.
- [15] Pokhrel S. No Title EAENH. *Αρχη* 2024;15:37–48.
- [16] Adams P, Bridgwater T, Lea-Langton A, Ross A, Watson I. *Biomass Conversion Technologies*. Elsevier Inc.; 2017. <https://doi.org/10.1016/B978-0-08-101036-5.00008-2>.
- [17] Mandley SJ, Daioglou V, Junginger HM, van Vuuren DP, Wicke B. *EU bioenergy development to 2050*. *Renew Sustain Energy Rev* 2020;127:109858. <https://doi.org/10.1016/j.rser.2020.109858>.
- [18] Dimitriadis A, Bergvall N, Johansson AC, Sandström L, Bezergianni S, Turlakidis N, et al. *Biomass conversion via ablative fast pyrolysis and hydroprocessing towards refinery integration: Industrially relevant scale validation*. *Fuel* 2023;332. <https://doi.org/10.1016/j.fuel.2022.126153>.
- [19] Tóth Á, Suta A, Pimentel J, Argoti A. *A comprehensive, semi-automated systematic literature review (SLR) design: Application to P-graph research with a focus on sustainability*. *J Clean Prod* 2023;415. <https://doi.org/10.1016/j.jclepro.2023.137741>.
- [20] Alidoosti Z, Ahmad sadegheih, Govindan K, Pishvae MS, Mostafaeipour A, Hossain AK. *Social sustainability of treatment technologies for bioenergy generation from the municipal solid waste using best worst method*. *J Clean Prod* 2021;288:125592. <https://doi.org/10.1016/j.jclepro.2020.125592>.
- [21] Rani P, Mishra AR, Saha A, Pamucar D. *Pythagorean fuzzy weighted discrimination-based approximation approach to the assessment of sustainable bioenergy technologies for agricultural residues*. *Int J Intell Syst* 2021;36:2964–90. <https://doi.org/10.1002/int.22408>.
- [22] Mofijur M, Kusumo F, Rizwanul Fattah IM, Mahmudul HM, Rasul MG, Shamsuddin AH, et al. *Resource recovery from waste coffee grounds using ultrasonic-assisted technology for bioenergy production*. *Energies* 2020;13. <https://doi.org/10.3390/en13071770>.
- [23] Danso-Boateng E, Achaw OW. *Bioenergy and biofuel production from biomass using thermochemical conversions technologies—a review*. vol. 10. 2022. <https://doi.org/10.3934/energy.2022030>.
- [24] Dotzauer M, Radtke KS, Jordan M, Thrän D. *Advanced SQL-Database for bioenergy technologies - A catalogue for bio-resources, conversion technologies, energy carriers, and supply applications*. *Heliyon* 2024;10:1–14. <https://doi.org/10.1016/j.heliyon.2024.e25434>.
- [25] Eloka-Eboka AC, Chetty R. *The Contribution of Bioenergy in the Renewable Energy Technology Mix: Research Perspective*. *J Phys Conf Ser* 2019;1378. <https://doi.org/10.1088/1742-6596/1378/2/022053>.
- [26] Ochieng R, Gebremedhin A, Sarker S. *Integration of Waste to Bioenergy Conversion Systems: A Critical Review*. *Energies* 2022;15. <https://doi.org/10.3390/en15072697>.
- [27] Negi H, Suyal DC, Soni R, Giri K, Goel R. *Indian Scenario of Biomass Availability and Its Bioenergy-Conversion Potential*. *Energies* 2023;16:1–17. <https://doi.org/10.3390/en16155805>.
- [28] Ufitikirezi J de DM, Filip M, Ghorbani M, Zoubek T, Olšan P, Bumbálek R, et al. *Agricultural Waste Valorization: Exploring Environmentally Friendly Approaches to Bioenergy Conversion*. *Sustain* 2024;16:1–24. <https://doi.org/10.3390/su16093617>.
- [29] Liao M, Yao Y. *Applications of artificial intelligence-based modeling for bioenergy systems: A review*. *GCB Bioenergy* 2021;13:774–802. <https://doi.org/10.1111/gcbb.12816>.
-

- [30] Güleç F, Okolie JA. Decarbonising bioenergy through biomass utilisation in chemical looping combustion and gasification: a review. *Environ Chem Lett* 2024;22:121–47. <https://doi.org/10.1007/s10311-023-01656-5>.
- [31] Lee J, Kraus KL, Couldwell WT. Use of the h index in neurosurgery: Clinical article. *J Neurosurg* 2009;111:387–92. <https://doi.org/10.3171/2008.10.JNS08978>.
- [32] Hauer MP, Hofmann XCR, Krafft TD, Zweig KA. Quantitative analysis of automatic performance evaluation systems based on the h-index. *Scientometrics* 2020;123:735–51. <https://doi.org/10.1007/s11192-020-03407-7>.
- [33] Bihari A, Tripathi S, Deepak A. A review on h-index and its alternative indices. *J Inf Sci* 2023;49:624–65. <https://doi.org/10.1177/01655515211014478>.
- [34] Hunt GE, Cleary M, Walter G. Psychiatry and the hirsch h-index: The relationship between journal impact factors and accrued citations. *Harv Rev Psychiatry* 2010;18:207–19. <https://doi.org/10.3109/10673229.2010.493742>.
- [35] Hirsch JE, Buela-Casal G. The meaning of the h-index. *Int J Clin Heal Psychol* 2014;14:161–4. [https://doi.org/10.1016/S1697-2600\(14\)70050-X](https://doi.org/10.1016/S1697-2600(14)70050-X).
- [36] Liu X. Full-Text Citation Analysis : A New Method to Enhance. *J Am Soc Inf Sci Technol* 2013;64:1852–63. <https://doi.org/10.1002/asi>.
- [37] Suharsiwi S, Suradika S, Nurmulia F. Map of Thematic Learning at Elementary School in the Pandemic Period (Study at Jakarta, Depok, dan Tangerang Areas). *J Obs J Pendidik Anak Usia Dini* 2023;7:3727–36. <https://doi.org/10.31004/obsesi.v7i3.3337>.
- [38] Basyari IW, Segara NB, Fhazarwati D. Utilizing thematic maps to develop Indonesia natural resources analytical skills. *IOP Conf Ser Earth Environ Sci* 2021;683. <https://doi.org/10.1088/1755-1315/683/1/012054>.
- [39] F. G. Assis LF, Ferreira KR, Vinhas L, Maurano L, Almeida C, Carvalho A, et al. TerraBrasilis: A Spatial Data Analytics Infrastructure for Large-Scale Thematic Mapping. *ISPRS Int J Geo-Information* 2019;8:513. <https://doi.org/10.3390/ijgi8110513>.
- [40] Sagita L, Prahmana RCI. The Visualization of the Impact of Covid-19 On Education Field: A Bibliometric Study. *Khizanah Al-Hikmah J Ilmu Perpustakaan, Informasi, Dan Kearsipan* 2022;10:12–24. <https://doi.org/10.24252/kah.v10i1a2>.
- [41] Ariona VD, Inayati NL, Apriantoro MS, Ashfahany A El, Tjandra EA. Charting the Course of Islamic Education Management Research: A Comprehensive Bibliometric Analysis for Future Inquiry. *Munaddhomah J Manaj Pendidik Islam* 2023;4:950–63. <https://doi.org/10.31538/munaddhomah.v4i4.711>.
- [42] Rusliana N, Komaludin A, Firmansyah MF. A Scientometric Analysis of Urban Economic Development: R Bibliometrix Biblioshiny Application. *J Ekon Pembang* 2022;11:80–94. <https://doi.org/10.23960/jep.v11i2.484>.
- [43] Kementerian Energi dan Sumber Daya Mineral. *Buku Saku Pengembangan Bioenergi Tahun 2022* 2022.
- [44] Nyambu U, Semmler W. Climate change and the transition to a low carbon economy – Carbon targets and the carbon budget. *Econ Model* 2020;84:367–76. <https://doi.org/10.1016/j.econmod.2019.04.026>.
- [45] Linnenluecke MK, Han J, Pan Z, Smith T. How markets will drive the transition to a low carbon economy. *Econ Model* 2019;77:42–54. <https://doi.org/10.1016/j.econmod.2018.07.010>.

- [46] Foxon TJ. *A coevolutionary framework for analysing a transition to a sustainable low carbon economy*. *Ecol Econ* 2011;70:2258–67. <https://doi.org/10.1016/j.ecolecon.2011.07.014>.
- [47] Meyer L, Tsatsaronis G, Buchgeister J, Schebek L. *Exergoenvironmental analysis for evaluation of the environmental impact of energy conversion systems*. *Energy* 2009;34:75–89. <https://doi.org/10.1016/j.energy.2008.07.018>.
- [48] Ayodele FO, Mohammad N, Mustapa SI, Ayodele BV. *An overview of economic analysis and environmental impacts of natural gas conversion technologies*. *Sustain* 2020;12:1–18. <https://doi.org/10.3390/su122310148>.
- [49] Escamilla-Alvarado C, Pérez-Pimienta JA, Ponce-Noyola T, Poggi-Varaldo HM. *An overview of the enzyme potential in bioenergy-producing biorefineries* Carlos Escamilla-Alvarado. *J Chem Technol Biotechnol* 2016;92:906–24.
- [50] Rittmann BE. *Opportunities for renewable bioenergy using microorganisms*. *Biotechnol Bioeng* 2008;100:203–12. <https://doi.org/10.1002/bit.21875>.
- [51] Bonilla-Campos I, Nieto N, del Portillo-Valdes L, Egilegor B, Manzanedo J, Gaztañaga H. *Energy Efficiency Assessment: Process Modelling and Waste Heat Recovery Analysis*. *Energy Convers Manag* 2019;196:1180–92. <https://doi.org/10.1016/j.enconman.2019.06.074>.
- [52] Hinker J, Wohlfahrt T, Drawing E, Paredes SFC, González DM, Myrzik JMA. *Adaptable energy systems integration by modular standardized and scalable system architectures necessities and prospects of any time transition*. *Energies* 2018;11:1–17. <https://doi.org/10.3390/en11030581>.
- [53] Papilo P, Marimin M, Hambali E, Machfud M, Yani M, Asrol M, et al. *Palm oil-based bioenergy sustainability and policy in Indonesia and Malaysia: A systematic review and future agendas*. *Heliyon* 2022;8:e10919. <https://doi.org/10.1016/j.heliyon.2022.e10919>.
- [54] Lo SLY, How BS, Leong WD, Teng SY, Rhamdhani MA, Sunarso J. *Techno-economic analysis for biomass supply chain: A state-of-the-art review*. *Renew Sustain Energy Rev* 2021;135:110164. <https://doi.org/10.1016/j.rser.2020.110164>.