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## **A Decade of Research on Biomass Materials in Residential Building Construction: A Bibliometric Analysis**

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**Abstract:** The application of biomass materials as construction components in the residential building sector has demonstrated substantial progress over the past decade, particularly in relation to sustainability challenges and carbon emission mitigation. The aim of this study is to examine scientific trends related to this subject through a bibliometric methodology encompassing 116 articles published in the database. Scopus during the period 2014 to 2024. The analytical process was carried out using VOSViewer and Biblioshy software to facilitate data visualization and to explain the patterns of relationships between researchers, keywords, and publication trajectories. The objectives of this study are: (1) to describe publication trends related to Biomass Materials in Residential Building Construction during the previous decade; (2) to reveal the most productive journals in disseminating literature on this subject; (3) to map the most active authors, institutions, and countries, along with the international collaborative networks between them; (4) to investigate the main themes, keywords, and research topics prevailing in the domain; (5) to ascertain the countries that show the highest productivity in linking biomass topics to educational planning; and (6) to identify the most frequently cited references in related scientific works. (7) The evolution of each theme in the last decade. The analysis **results revealed** that the publication trend experienced an annual growth of 9.04% with peak productivity in 2022 and 2024. Leading journals such as *Energies*, *Renewable Energy*, and *Journal of Cleaner Production* has become a major source of publications, with article distribution reflecting a focus on renewable energy and sustainable buildings. Authors such as Luisa F. Cabeza and institutions from Italy and China demonstrate high productivity, while countries such as Switzerland and Sweden stand out in terms of scholarly impact through significant average citations per article. Thematic mapping shows a shift away from basic themes such as *residential building* and *biomass* towards strategic themes such as *carbon emission*, *renewable energy integration*, and *optimization*. Temporal keyword analysis shows that from 2018 to 2024, there has been an increasing focus on the issues of building decarbonization, energy efficiency, and renewable energy transition. In addition, the most frequently cited global references come from highly reputable energy and sustainability journals, while local references show a tendency towards contextual and applied approaches. The findings of this study indicate that biomass research in residential building construction is not only developing quantitatively, but also experiencing a deepening of themes and an expansion of global collaboration.

**Keywords:** Bibliometrics, Biomass, Residential building construction, Sustainable architecture, Renewable energy, Research trends, Low carbon emissions

### **Introduction**

The use of biomass materials in the construction sector is gaining increasing attention every year in the context of sustainability and material innovation. Biomass itself is known as a renewable energy source, and it is now being utilized in home construction. Biomass will be innovated as a more environmentally friendly and economical building material. Research by Gracia and Cruz shows that biomass materials can replace conventional materials, providing more sustainable benefits and reducing the environmental impact of conventional building material production (Adeleke et al., 2021; Cruz & García-Uitz, 2024). The use of managed biomass from sargassum and organic materials processed into building materials confirms that

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switching from using biomass as a fuel to using construction materials can provide significant added value in supporting more sustainable construction practices. (Cruz & García-Uitz, 2024).

The housing sector faces several major challenges in carbon emission disclosure and sustainability reporting transparency (Nur Afni Nurul Nur Aeni & Etty Murwaningsari, 2023). Consequently, the construction sector is required to address energy efficiency and green technology issues. Research by Judijjanto et al. showed that the application of renewable energy and green technology can reduce carbon emissions (Judijjanto et al., 2023). Data from the IEA (2021) shows that the housing sector contributes 37% of carbon emissions, with house walls being a major contributor. Research also reveals that biomass has significant potential to support low-carbon housing in remote areas. Another advantage of using biomass in construction is its mechanical properties. A study by Syasiak et al. explains that biomass, particularly pine wood, exhibits frictional and strength properties that support its application in construction (Stasiak et al., 2020). Furthermore, biomass materials act as good thermal insulators and can contribute to energy savings in buildings and provide comfort for occupants (Adeleke et al., 2021). Biomass materials support green construction practices, for example, research by Akib and Bhardwaj states that materials made from biomass composition derived from fungi make them environmentally friendly and biodegradable (Akib et al., 2024; Bhardwaj et al., 2021). The use of biomass-derived materials in construction not only provides environmental benefits but also encourages local economic growth by creating new opportunities in developing new products and techniques on a local scale (Adeleke et al., 2021).

Considering the importance of managing local resources for use as biomass materials in the housing construction sector, the challenges of systematically mapping biomass research trends in the residential sector are crucial, particularly in the context of sustainability and carbon emission reduction. Effective mapping will help clarify research directions and make informed decisions about implementing biomass materials in the housing sector. Aeni and Murwangsari's research explains that lack of clarity in disclosing carbon emissions can lead to difficulties in mapping broader social and environmental impacts on related sectors (Nur Afni Nurul Nur Aeni & Etty Murwaningsari, 2023). To address the gap in non-strategic mapping of biomass materials in the housing sector, a comprehensive bibliometrics is needed in this field. Considering the above discussion, this study aims to analyze, present, and describe research trends on biomass materials in residential construction using bibliometric analysis. Based on this objective, this study presents six questions to be addressed in this study as follows: 1) What are the publication trends related to *Biomass Materials in Residential Building Construction* in supporting innovative learning over the last decade; 2) Which journals are the most productive in publishing literature on *Biomass Materials in Residential Building Construction*; 3) Who are the most productive authors, institutions and countries in producing research related to *Biomass Materials in Residential Building Construction*; 4) How are the relationships between researchers and international collaboration patterns; 5) What are the main themes, keywords, and most dominant research topics in the topic *Biomass Materials in Residential Building Construction*; 5) Which country is the most productive in emphasizing the topic of *Biomass Materials in Residential Building Construction* in classroom planning; 6) What references are frequently cited in emphasizing the topic of *Biomass Materials in Residential Building Construction*; 7) How is the thematic evolution of *Biomass Materials in Residential research? Building Construction* from year to year. Through comprehensive analysis, this research is expected to contribute to the development and innovation of biomass materials in the residential construction sector.

## Method

This study employs a quantitative descriptive research framework, employing a bibliometric analytical approach. The aim of this review is to examine publication trends, collaborative networks of authors, and dominant themes in the field of biomass in the context of residential building construction. The bibliometric methodology facilitates the systematic mapping of scientific output and the structured organization of knowledge derived from publication metadata obtained from databases. Scopus over the previous decade (Setyanto et al., 2023). The data collection process was conducted through the Scopus scientific database, which is recognized for its wide coverage of multidisciplinary research types. (Taqiyyah & Soebagyo, 2022). To facilitate this goal, the investigated population includes all scientific publications related to the subject of "biomass materials in dwellings" that are accessible in the database. Scopus. The selected sample was described by a strategy that included Boolean keyword searches such as "biomass" AND "residential buildings" AND "construction" AND "biomass waste" OR "agricultural waste" AND ("construction materials" OR "building materials"), applied to titles, abstracts, and keywords, along with specific criteria limited to well-indexed articles and conference proceedings, publications written in English, and those disseminated from 20214 to 2024. After the screening process, a total of 116 articles were obtained as a suitable sample for analysis. To analyze the data effectively, the main instruments used in this study consisted of the VOS viewer software and

Bibliosinhy, which are based on the Bibliometric R package. Both tools were used to process the data, dissect and visualize collaborative networks of authors, institutions, countries, keyword occurrences, citation and co-citation networks, as well as analyze thematic trends and evolutions. Furthermore, OpenRefine software was used to eliminate duplicate data entries.

The methodology for carrying out this research begins with a meta-retrieval process sourced from the database. Scopus will be searched using predefined Boolean keyword searches. The data will then be refined using OpenRefine to detect duplicate and irrelevant publications, while retaining publications that align with the established inclusion criteria. The data will then undergo analytical scrutiny. Descriptive analysis will be used to assess publication growth, source journals, and document types. Network analysis will utilize VOSviewer to visualize collaborative interactions between authors, institutions, and countries. A concluding analysis, including thematic analysis and keyword mapping, will be conducted using Biblioshy, which will illuminate key themes and developments in the publication landscape.

## Results

Research using bibliometric analysis methodology seeks to systematically organize, examine, and visualize the evolution of scientific trends regarding Biomass Materials in Residential Housing. The investigation is categorized into seven different objectives, which include trends and progress in publications, the most productive academic journals, the most productive authors and their interconnections, the most frequently cited scientific references, the most frequently used keywords, and the development of research themes. In general, author networks, co-occurrences, and keywords will be subjected to analysis and visualization through VOSviewer, while other categories will be examined using Bibliometrix. Presented below are the research findings that correspond to each of the aforementioned categories.

### Publication Trends & Developments

Trends and developments in publications from research on the theme of *Biomass Materials in Residential Building Construction* was collected through Scopus with a total of 116 documents. Based on general data analysis using Bibliometrix software, comprehensive information about the distribution of article publications, the time span of article publications, the average age of documents, the average citations per document, keywords from authors, author keywords, documents written by one author, international co-authorship, co-authors per document, the country of the corresponding author and references are available in Table 1.

Table 1. Summarize of the review (main information)

Description	Results
<b>Play Information about Data</b>	
Timespan	2014:2024
Sources ( Journals & Conference )	86
<b>Documents</b>	
Documents	136
Annual Growth Rate %	9.04%
Document Average Age	5.18
Average Citations Per Document	24.92
<b>References</b>	
Documents Contents	5007
Keyword Plus ( Id )	1279
Author's Keywords (DE)	485
<b>Authors</b>	
Authors	491
Authors Of Single-Authored Documents	7
International Co- Authorships %	22.79%
Co- Authors Per Documents	3.99
<b>Documents Types</b>	
Article	100
Conference Paper	36

This study explains, in Table 1 the bibliometric review covers publications from 2014 to 2024 with a total of 136 documents originating from journals and conference proceedings. The annual growth rate reaches 9.04% indicating a fairly stable trend of increase in the last decade. The average age of the documents is 5.18 years and the average citation per document is 24.92 revealing the relevance and scientific influence of this topic is quite high. A total of 5007 references are used, indicating a comprehensive and thorough examination of the library scope. The distinguished keywords include 1279 Keyword Plus (ID) and 485 Author Keyword (DE), reflecting the diversity of topics and the potential for thematic investigations in the research domain. From an authorship perspective, there are 491 contributors, with only 7 papers produced by individual authors. The international collaboration rate is recorded at 22.79%, while the average number of authors per publication reaches 3.99, highlighting a clear trend towards collaborative research efforts.

In terms of document classification, the dominant type consists of journal articles, totaling 100 documents, while the remainder are conference proceedings, totaling 36 documents. This distribution proves that most of the analyzed literature comes from peer-reviewed publications, which usually have a high level of scientific rigor and reliability. Meanwhile, Figure 2 explains the trend of the number of scientific publications each year from 2014 to 2024. At the beginning of the analyzed time frame, the volume of scientific articles was relatively modest, starting with 8 articles in 2014 and rising to 10 articles in 2015, followed by a slight decrease to 9 articles in 2016. However, a marked reduction was observed in 2017, with only 6 publications documented. To see the trend of the number of scientific publications from 2014 to 2024 can be seen in Figure 2.

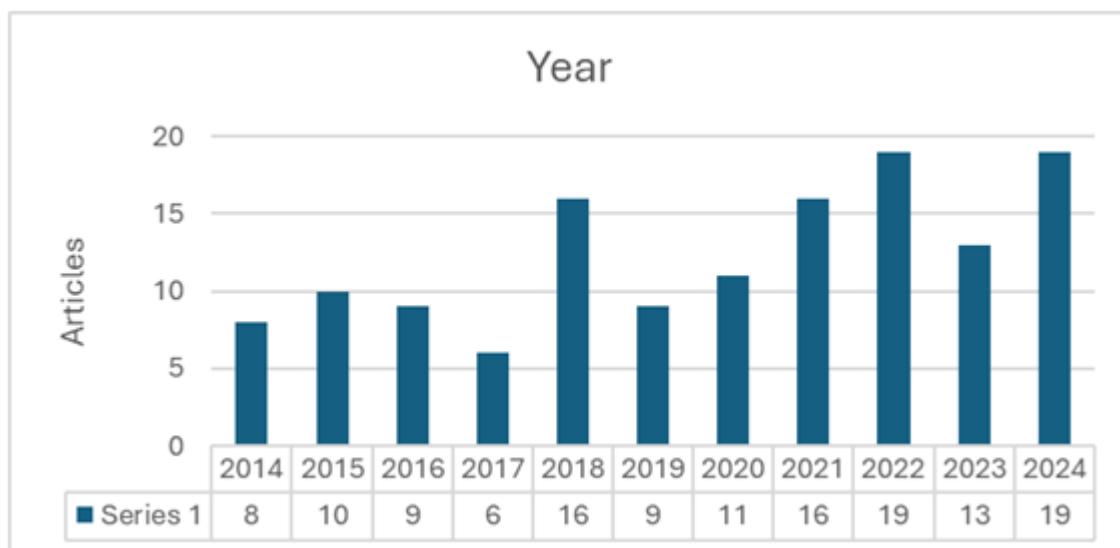


Figure 1. Progression of number of publications from 2014 to 2024

In Figure 1, at the beginning of the period the number of articles was relatively low, starting from 8 articles in 2014 and increasing to 10 articles in 2015 and 9 articles in 2016. However, there was a significant decrease in 2017 with only 6 publications. In 2018, there was a large surge, culminating in 16 articles, indicating an increased focus on the subject matter being examined. Subsequently, the number of scientific publications showed variability, with a small decrease in 2019 (9 articles) and a progressive escalation in 2020 (11 articles) and 2021 (16 articles). The peak of publication quantity was reached in 2022, recording a total of 19 articles, followed by a small decrease in 2023 (13 articles), and again increasing to 19 articles in 2024. Overall, the trajectory of publication numbers shows an upward trend over the previous decade, with a significant expansion post-2017. This phenomenon underscores the increasing interest and academic significance attributed to the research theme during that temporal segment.

### Most Productive Journal

To identify the primary publication sources in this field of study, an analysis of the journals most frequently publishing related articles was conducted. The results are presented in Table 2, which shows the ten most productive journals based on the number of publications and total citations during the analyzed period. Table 2 shows the ten most productive journals that are the primary sources of publications related to the topics analyzed. The journal *Energies*, published by MDPI, ranked first with a contribution of 11 articles (8.08%) and

a total of 178 citations . It was followed by *Energy and Buildings* from Elsevier BV with 8 articles (5.88%) and the highest total citations among all, namely 305 citations.

Table 2. Top-10 most relevant sources

Journal	TAP (%)	TC	Publisher
Energies	11 (8.08%)	178	MDPI
Energy And Buildings	8 (5.88%)	305	Elsevier BV
Renewable Energy	6 (4.41%)	253	Elsevier Ltd
Sustainability ( Switzerland )	5 (3.67%)	286	MDPI
Applied Energy	4 (2.94%)	61	Elsevier BV
Buildings	4 (2.94%)	45	Elsevier BV
Energy	3 (2.2%)	200	Elsevier BV
Energy Conversion And Management	3 (2.2%)	187	Elsevier Ltd
Journal Of Cleaner Production	3(2.2%)	964	Elsevier Ltd
Journal Of Physics : Conference Series	3(2.2%)	102	IOP

*Renewable Energy* and *Sustainability Journal ( Switzerland )* also occupies a significant position, contributing 6 and 5 articles respectively, with a total of 253 and 286 citations . Most of the journals in this list are published by Elsevier , either through BV or Ltd entities, which shows the dominance of this publisher in the fields of energy, buildings and sustainability. In addition, the *Journal of Cleaner Production* recorded the highest total citations of 964 despite contributing only 3 articles, indicating the very high quality and scientific impact of the articles it published.

Therefore, most of the publications in this study come from reputable international journals, particularly those published by Elsevier and MDPI , focusing on energy, buildings, and sustainability. This confirms that the topics reviewed are highly relevant in the global scientific discourse and are published in high-impact journals in their respective fields.

### Most Productive Author

Based on Table 1, there are 491 authors involved in 136 publications with an average of 3.99 authors per document , indicating high collaboration in research related to this topic. To identify the most active contributors to these publications, Table 3 presents the ten most productive authors along with bibliometric indicators such as *h- index* , *g- index* , *m- index* , total citations (TC), and their home institutions.

Table 3. Top-10 most profiled authors

Author	h_index	g_index	m_index	TC	NP	PY_start	Affiliation
Cabeza Luisa F.	4	4	0.25278	903	4	2015	Xi'an Jiaotong University
Baratieri Marco	3	3	0.17361	99	3	2014	Chiang Mai University
Borri Emiliano	3	3	0.34722	70	3	2020	Dalian University Of Technology
Anoop S.	2	2	0.15417	12	2	2017	Shanxi University
Aye Lu	2	2	0.27778	64	2	2021	University Of La Rioja
Calise Francesco	2	2	0.15417	79	2	2017	Aristotle University
Cappiello	2	2	0.27778	53	2	2021	Politecnico of Milan
Francesco L.							
Carlon Elisa	2	2	0.12639	59	2	2015	Shihezi University
Charalampidis	2	2	0.23125	57	2	2020	Otto- Von - Guericke-University
Antonios							
D'accadia Massimo	2	2	0.15417	79	2	2017	The University Of Melbourne
Dentistry							

Note : H -index = an author has an h- index of 'h' when they have h papers that have been cited h times at least , G-Index = is where the top G articles have together received G citations , M- index = is the H- index divided by the number of years that an the author has been active , Tc = Total Citations , Np = Number of papers , Py\_Start = publication year start

Table 3 shows that the author **Luisa F. Cabeza** from **Xi'an Jiaotong University** is the most productive and most influential author, with the highest *h*-index and *g*-index (4 each), and total citations reaching **903** from 4 publications since 2015. This figure is also reflected in the highest *m*-index among other authors (0.25278), indicating consistent contributions over a relatively long period.

Other authors who are also active are **Baratieri Marco** ( Chiang Mai University ) and **Borri Emiliano** ( Dalian University of Technology), each with 3 publications and total citations of 99 and 70. Meanwhile, several other authors such as **Ave Lu** , **Cappiello Francesco L.** , and **Charalampidis Antonios** began his contributions in 2020–2021, with a relatively high *m*-index indicating productivity in a shorter period. Contributions come from leading countries and institutions such as China, Italy, Germany, Australia, and Thailand, demonstrating global engagement in this research topic.

Thus, the most productive authors in this field come from renowned institutions and show variation in terms of number of publications, total citations , and rate of scientific productivity ( *m*-index ). The dominance of Luisa F. Cabeza demonstrates her central role in the development of this topic, while contributions from new authors with high *m*-indexes indicate a growing and expanding global research interest.

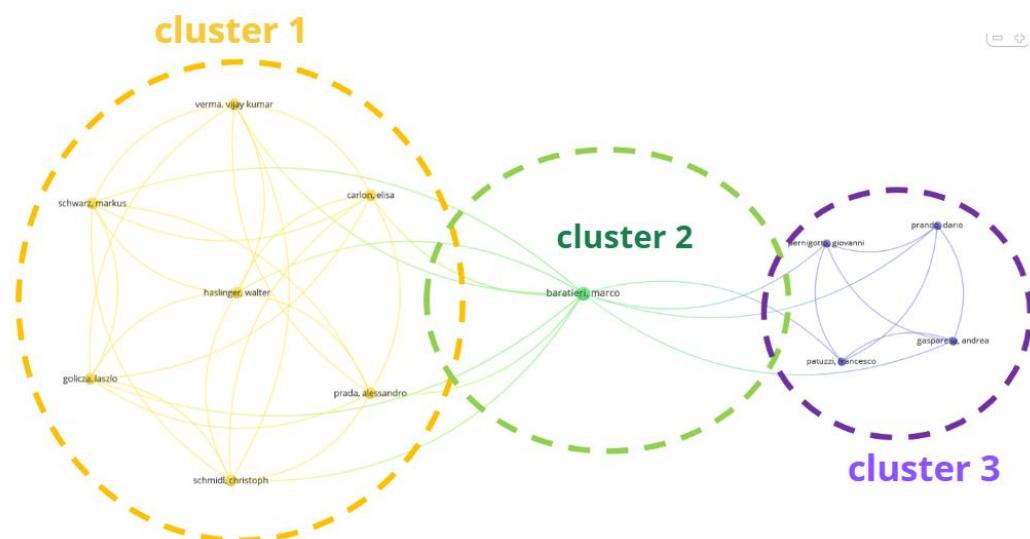


Figure 2. Collaborative network between authors on biomass materials in residential building construction

In line with the identification of the most productive authors in Table 3, Figure 2 visualizes **the collaboration network between authors** in the topic of *Biomass Materials in Residential Building Construction* uses mapping from VOSviewer . The network is divided into **three main clusters** , which indicate collaborative groups based on the frequency of article co-authorship.

- **Cluster 1 (yellow)** is the largest and densest collaborative group, involving authors such as *Verma Ajay Kumar* , *Schweiker Markus* , and *Gkoktsi Alasio* . The authors in this cluster appear to be closely networked with each other , indicating a high level of collaboration among them.
- **Cluster 2 (green)** is led by *Baratieri Marco* — one of the most prolific authors who also appears in Table 3. He acts as a liaison between the clusters, collaborating with authors from both cluster 1 and cluster 3, demonstrating a central role in the research network.
- **Cluster 3 (purple)** contains authors such as *Arrigoni Alessandro* , *Preti Luca* , and *Pittaluga Andrea* , who form their own collaborative group but remain connected to other clusters through cross-group collaborators.

Thus, this visualization reinforces the data in Table 3, showing that authors with high productivity tend to play a central role in scientific collaboration networks. The presence of interconnected clusters demonstrates that biomass research in residential building construction is multidisciplinary and globally collaborative.

## Citation Analysis

### Corresponding Author's Countries

Based on Table 1, **136 documents** were analyzed, with contributions from various international authors. To understand the geographic distribution of this research, Figure 3 illustrates the country of origin of the corresponding authors and distinguishes between national publications (SCPs) and international collaborations (MCPs).

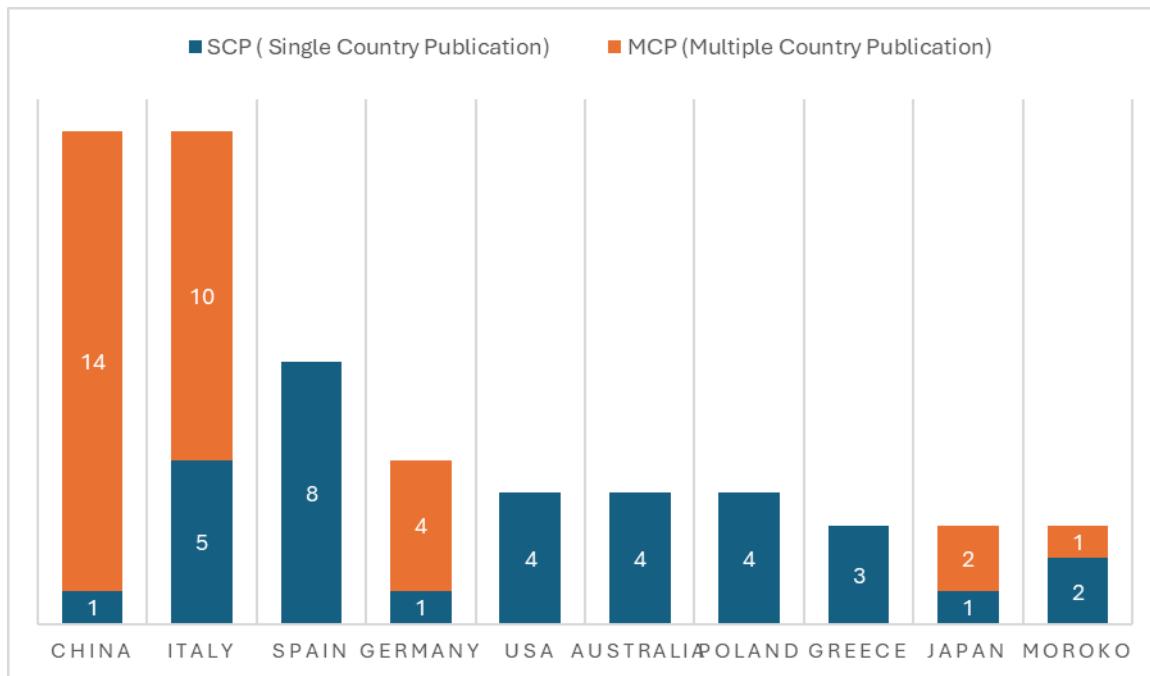


Figure 3. Most relevant countries

Figure 3 shows that **China and Italy are the two countries with the largest contributions to biomass** -related publications . *materials in residential building* China has a total of **15 publications** , dominated by international collaborations ( *Multiple Country Publications/MCP* ) with 14 documents, only 1 is national ( *Single Country Publication /SCP* ). A similar situation also occurs in Italy, with a total of **15 publications** (10 MCP and 5 SCP). Spain followed with 8 publications , all of which were SCPs, demonstrating the dominance of local research. Countries such as Germany , the United States , Australia , and Poland each contributed 4 publications, most of which were the result of domestic collaborations.

Interestingly, countries like **Japan** and **Morocco** are also beginning to contribute, albeit in smaller numbers, but with a significant share of international publications. This visualization demonstrates that research topics related to biomass in residential construction have a broad international reach. Countries like **China and Italy** are not only active in terms of the number of publications but also demonstrate **a high level of international collaboration**, reinforcing the importance of cross-border cooperation in the development of sustainable research.

### Most Prolific Countries

Following on from the previous analysis of the distribution of citations and publications by country, Table 4 provides a comprehensive overview of the ten most productive countries in the topic of biomass for residential building construction. This analysis not only highlights total citations (TC), but also presents the average citations per article, the number of articles , and the frequency of contributions , all of which reflect the quality and intensity of research per country.

Based on the data, Italy recorded the highest number of citations ( TC = 248 ) with 90 contributed articles , indicating that this country is active and consistent in producing publications. However, in terms of average citations per article , the country only recorded 16.5 , which indicates that although productive, not all articles have high citation power. In contrast, Switzerland and Sweden showed very high average citation numbers , namely 199 and 104 , even though their article contributions were relatively low, only 23 and 45 articles , respectively . This indicates that although their contributions are not large quantitatively, the quality and influence of their articles are very significant.

Table 4. Top 10 most prolific countries

Country	TC	Average Citations	Article	Frequent
Italy	248	16.50	90	
China	222	0.6042	72	
Sweden	208	104.00.00	45	
Spain	199	24.90	39	
Switzerland	199	199,000,000	23	
USA	154	30.80	20	
Japan	147	49,000,000	20	
Morocco	93	31.00.00	18	
Australia	91	0.9722	17	

China, as one of the countries with the most publications ( 72 articles ), has a low average citation rate of 0.60 , indicating challenges in ensuring the quality or relevance of articles within the scientific community. Other countries such as the USA, Japan, Morocco , and Australia also show interesting dynamics, where they may not be as dominant in terms of the number of publications, but some have competitive average citations -such as the USA (30.8) and Japan (49.0) -which reflect the quality of research that is worthy of consideration.

This table shows that scientific productivity can be measured not only by the number of articles published , but also by scientific influence, as reflected in the average citation rate per article . Countries like Switzerland and Sweden demonstrate that quality and influence can outweigh quantity, while Italy and China occupy strategic positions in terms of numerical contribution but need to be boosted in terms of citation capacity. These findings emphasize the importance of promoting research that is not only plentiful but also high-quality and has a global impact.

### Most Cited References

Based on Table 1, this study includes an analysis of 136 scientific documents published between 2014 and 2024, with an average document age of 5.18 years. The number of references collected reached 5007. From the total references, the most frequently cited publications were identified to understand the direction, focus, and main influences in this research field. Table 5 presents the 10 most cited publications in all the documents reviewed.

Table 4. Top 10th global cities documents

Paper	DOI	Total Citations	TC per Year	Normalized TC
Ürge-Vorsatz D, 2015, Renewable Sustainable Energy Rev	<a href="https://doi.org/10.1016/j.rser.2014.08.039">10.1016/j.rser.2014.08.039</a>	833	75.73	7.52
Wu R, 2017, Appl Energy	<a href="https://doi.org/10.1016/j.apenergy.2016.12.161">10.1016/j.apenergy.2016.12.161</a>	199	22.11	3.30
Su C, 2018, Energy Convers Manage	<a href="https://doi.org/10.1016/j.enconman.2018.10.005">10.1016/j.enconman.2018.10.005</a>	157	19.63	6.46
Yang S, 2023, Environ Sci Pollut Res	<a href="https://doi.org/10.1007/s11356-022-19764-0">10.1007/s11356-022-19764-0</a>	116	38.67	7.15
Sharafi M, 2015, Renew Energy	<a href="https://doi.org/10.1016/j.renene.2015.05.022">10.1016/j.renene.2015.05.022</a>	103	9.36	0.93
Heiskanen E, 2017, Renewable Sustainable Energy Rev	<a href="https://doi.org/10.1016/j.rser.2016.11.027">10.1016/j.rser.2016.11.027</a>	100	11.11	1.66
Zhao M, 2015, Energy Build	<a href="https://doi.org/10.1016/j.enbuild.2015.03.007">10.1016/j.enbuild.2015.03.007</a>	88	8.00	0.79
Charai M, 2021, J Clean Prod	<a href="https://doi.org/10.1016/j.jclepro.2021.126064">10.1016/j.jclepro.2021.126064</a>	87	17.40	3.01
Perea -Moreno MA, 2018, Sustainability	<a href="https://doi.org/10.3390/su10103407">10.3390/su10103407</a>	74	9.25	3.04
Dobravec V, 2021, Energy Sustainability Soc	<a href="https://doi.org/10.1186/s13705-020-00277-y">10.1186/s13705-020-00277-y</a>	66	13.20	2.28

Table 5 displays the total number of citations, citations per year, and *Normalized TC values*. This table provides an overview of the relative contribution of each article to the advancement of knowledge and the global literature map in this field. Table 5 summarizes the 10 most influential global publications in this study based on the highest number of citations. The most highly cited article is from Ürge-Vorsatz D (2015) published in *Renewable and Sustainable Energy Reviews*, with a total of 833 citations and an average of 75.73 citations per year, and a *Normalized TC* of 7.52. This demonstrates a significant contribution to the development of knowledge in the field of renewable energy and building efficiency. The next sequence is filled by Wu R (2017) in the journal *Applied Energy* with 199 citations, followed by Su C (2018) in *Energy Conversion and Management* with 157 citations. Interestingly, although the article by Yang S (2023) is the most recent, it has a very high *Normalized TC* (7.15), indicating a very strong early impact in the scientific community. In contrast, several publications with low citations, such as Zhao M (2015) and Sharifi M (2015), have relatively small *Normalized TCs*, indicating that despite their long publication history, their contributions are still not widely used as primary references.

The data in Table 5 confirms that publications are relevant, innovative, and fall within the domain of strategic topics such as *renewable Energy* and *sustainability* tend to have high academic influence, as seen in annual citation counts and *Normalized TC*. Furthermore, recently published but immediately high-impact articles, such as those by Yang S (2023), indicate a shift in research attention toward more contemporary and applicable approaches, such as the environmental impact of pollution and sustainability. After identifying the most frequently cited global references in Table 5, the analysis continued by examining the most frequently cited references locally within the reviewed documents. Table 6 presents the top 10 most frequently cited references within the analyzed literature, indicating a more contextual and specific focus and preference for the literature within a particular region or field of study.

Table 5. Top 10 most locally cited references

Cited References	Citations
Ogunjuyigbe ASO, Ayodele TR, Akinola OA	8
Duffie JA, Beckman WA, Solar Engineering Of Thermal Processes , (2013)	4
Ahmad J., Imran M., Khalid A., Iqbal W., Ashraf SR, Adnan M., Ali SF, Khokhar KS, Techno Economic Analysis Of A Wind-Photovoltaic-Biomass Hybrid Renewable Energy System For Rural Electrification : A Case Study Of Kallar Kahar, Energy, 148, Pp. 208-234, (2018)	3
Hu S., Yan D., Guo S., Cui Y., Dong B., A Survey On Energy Consumption And Energy Usage Behavior Of Households And Residential Building In Urban China, Energy Build , 148, Pp. 366-378, (2017)	3
2019 Annual Report On China Building Energy Efficiency , (2019)	2
Abas N., Kalair A., Khan N., Review Of Fossil Fuels And Future Energy Technologies, Futures , 69, Pp. 31-49, (2015)	2
Action E., Implementing The Energy Performance Of Buildings Directive ( Epbd ), Featuring Country Reports , (2016)	2
Al-Sulaiman FA, Hamdullahpur F., Dincer I., Performance Assessment Of A Novel System Using Parabolic Trough Solar Collectors For Combined Cooling , Heating , And Power Production , Renew . Energy, 48, Pp. 161-172, (2012)	2
Annual Report On China Building Energy Efficiency 2019, (2019)	2
Antipova E., Boer D., Guillen-Gosálbez G., Cabeza LF, Jimenez L., Multi- Objective Optimization Coupled With Life Cycle Assessment for Retrofitting Buildings , Energy Build , 82, Pp. 92-99, (2014)	2

Table 6 displays the most frequently cited references in the reviewed document set, reflecting the theoretical foundations or key data that authors frequently use in their studies. The reference with the highest number of local citations is the work of Ogunjuyigbe ASO et al. et al. who obtained **8 local citations**, indicating his dominant contribution in research related to local context-based energy systems.

Some other important references come from Duffie and Beckman (2013) on solar thermal systems (4 citations), as well as two articles from the journal *Energy* discussing hybrid energy systems and energy consumption behavior in urban residential buildings in China, each with 3 citations. There are also important policy documents such as the *Annual Report on China Building Energy Efficiency (2019)* which appears twice with the same citation frequency. Other references include a review of future energy technologies (Abas et al. , 2015), building energy performance (Action E, 2016), and building retrofit approaches using multi -objective optimization (Antipova et al. , 2014), all of which have two local citations.

This table indicates that the reviewed studies rely heavily on literature relevant to local and practical contexts, particularly those related to building energy efficiency, integrated renewable energy systems, and energy policy. Not only scientific articles but also annual reports and national policy documents are included as important references. This reflects the applied and contextual approach of the research, as well as the need for energy solutions tailored to specific regional conditions.

## Most Occurring Keywords

Bibliometric analysis, the frequency of keyword occurrence is an important indicator for identifying the main focus and thematic trends in a research field (Donthu et al., 2021). Figure 4 presents a visualization of the 50 most frequently used keywords by authors in studies on renewable energy, building efficiency, and sustainability, generated using the *Bibliometrix tool*. From Figure 4, it can be seen that the dominant topic that appears most frequently is *residential, building, housing, energy efficiency, biomass, energy utilization, and heating*. These keywords reflect the primary focus of research on energy efficiency in the residential sector and the use of alternative resources such as biomass.



Figure 3. Top-50 author keywords , frequency , & proportion ( Source : Authors ' own elaboration , using Bibliometrix )

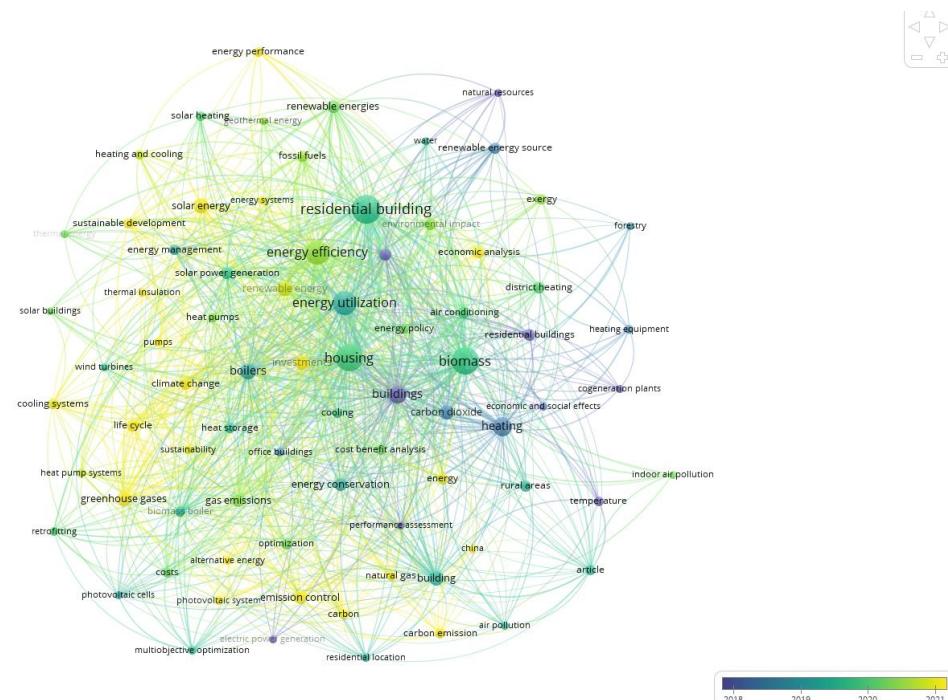


Figure 4. Network map of author keywords by year

Keyword network mapping in bibliometrics is very useful for revealing the conceptual structure and dynamics of research in a field (Cobo et al., 2011) . Figure 5 shows a map of the most frequently used keyword networks by authors, mapped by their time of appearance from 2018 to 2021, using VOSviewer software. Meanwhile, Figure 5 enriches the insight by showing the temporal evolution of the keywords. Earlier topics such as *energy efficiency* and *residential building* becomes the center of the network, signifying its establishment as a core issue. While newer, yellow keywords, such as *carbon emissions*, *retrofitting* , *economics analysis* , and *smart buildings* , shows the direction of research development towards a more multidimensional approach, covering environmental, economic and technological aspects.

The combined analysis of keyword frequency (Figure 4) and keyword temporal network map (Figure 5) reveals the direction and dynamics of research development in the field of sustainable energy and buildings over the past few years. The combination of these two visualizations shows that while energy efficiency and residential buildings remain the foundation of research, there is a shift in interest towards more complex and sophisticated issues, including carbon emissions, environmental impact reduction, and renewable energy integration.

### Thematic Evolution

The growing demand for sustainable buildings has driven the development of research focused on the use of alternative biomass-based materials. In the context of residential construction, this approach aims not only to reduce the carbon footprint but also to improve energy efficiency and indoor environmental quality (Fernández et al., 2024; Garcia et al., 2014) . Figure 6 depicts a thematic map of the evolution of research on biomass materials for residential building construction, showing how themes such as "*residential building* " , "*biomass* " , and "*housing* " have become *basic themes* —indicates that these topics have high centrality in this field, even though their level of development is still limited.

The thematic evolution map in Figure 6 is the result of a bibliometric analysis that illustrates the dynamics of research related to biomass materials in residential building construction. This analysis was developed to understand how scientific themes evolve over time based on the dimensions of relevance (centrality) and depth of development (density).

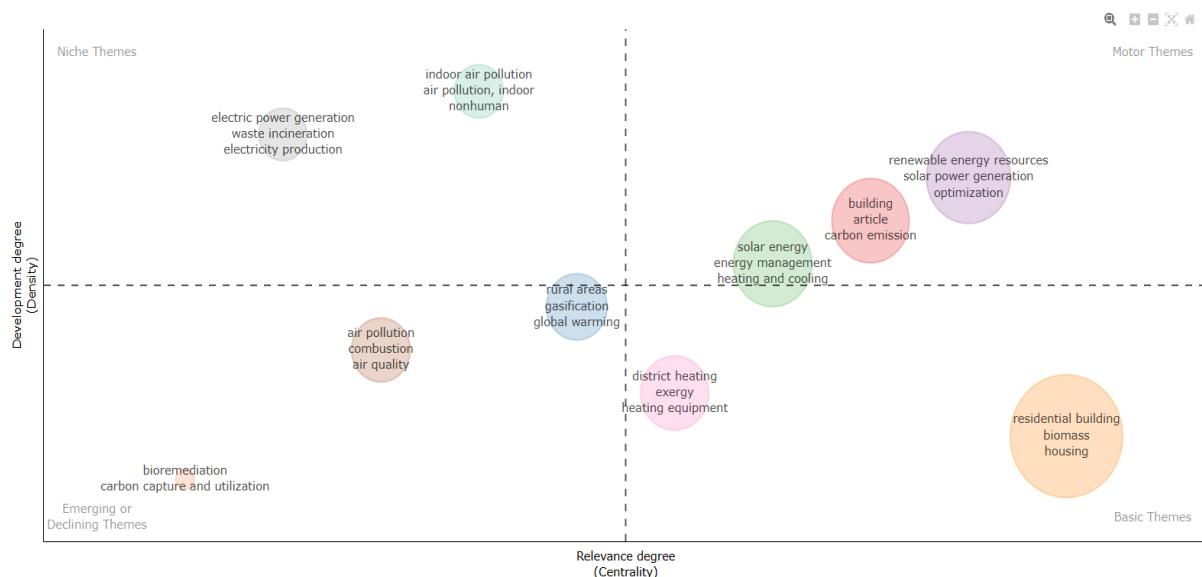


Figure 5. Thematic evolution map of biomass materials in residential building construction research

#### Bottom Right Quadrant – Basic Themes

Basic Themes are basic themes in biomass research that tend to be general yet essential, as they serve as the foundation for more advanced themes (Shi et al., 2021) . In this quadrant, themes such as *residential building* , *biomass* , and *housing* are in the *basic category themes* , meaning these themes are central to the research field but have not been developed in depth. This indicates that these topics form an important foundation and are continually discussed in the literature, but are still open to further, deeper, and more specific exploration.

#### Upper Right Quadrant – Motor Themes

Motorcycle Themes is a theme like renewable Energy and carbon emissions are key drivers in sustainable architecture, as they offer direct solutions to the climate crisis. (Zhao et al., 2023) . In Figure 6, themes such as renewable energy resources, solar power generation , optimization , and carbon emissions and buildings The article demonstrates high development and high centrality . This means the topic is not only popular but also actively developing and driving the direction of biomass research in building construction. This topic generally relates to the integration of biomass into energy systems and carbon emission reduction strategies.

#### Upper Left Quadrant – Niche Themes

Niche Themes are themes such as indoor air pollution and waste Incineration is often in a specialized context with a narrow but technical and detailed focus. (Liao et al., 2019) . In Figure 6, topics such as *indoor air pollution* , *waste incineration* , and *electricity Production* occupies a niche position . This indicates that these themes are developing independently, but lack strong links to other major themes in the field. Research on these themes is typically more technical in nature or focused on specific applications.

#### Lower Left Quadrant – Emerging or Declining Themes

Emerging or Declining Themes in this quadrant can indicate new research directions or areas that are starting to be abandoned due to limited applicability (Ge et al., 2022) . In Figure 6, themes such as *bioremediation* and *carbon capture and utilization* is included in the *emerging category or declining* This topic has little relevance and development, possibly because it is still relatively new in the context of residential buildings or is starting to be abandoned in current research trends.

This thematic map shows that biomass research in residential building construction is still very much focused on basic issues such as *housing* , *residential building* , and *biomass* , but are beginning to shift toward integration with renewable energy systems and carbon emission reduction. This reflects a transition from a passive approach to an active and integrated approach to sustainable development. Therefore, research opportunities remain wide open to explore the relationship between biomass and energy performance, indoor air quality, and the optimization of material technology in modern, environmentally friendly residential architecture. Continuing from the thematic classification above, Figure 7 presents **the temporal evolution of keywords** , showing the trend in the use of key terms over the period 2014–2024. This graph shows when a topic first emerged and how long it was actively discussed in the literature:

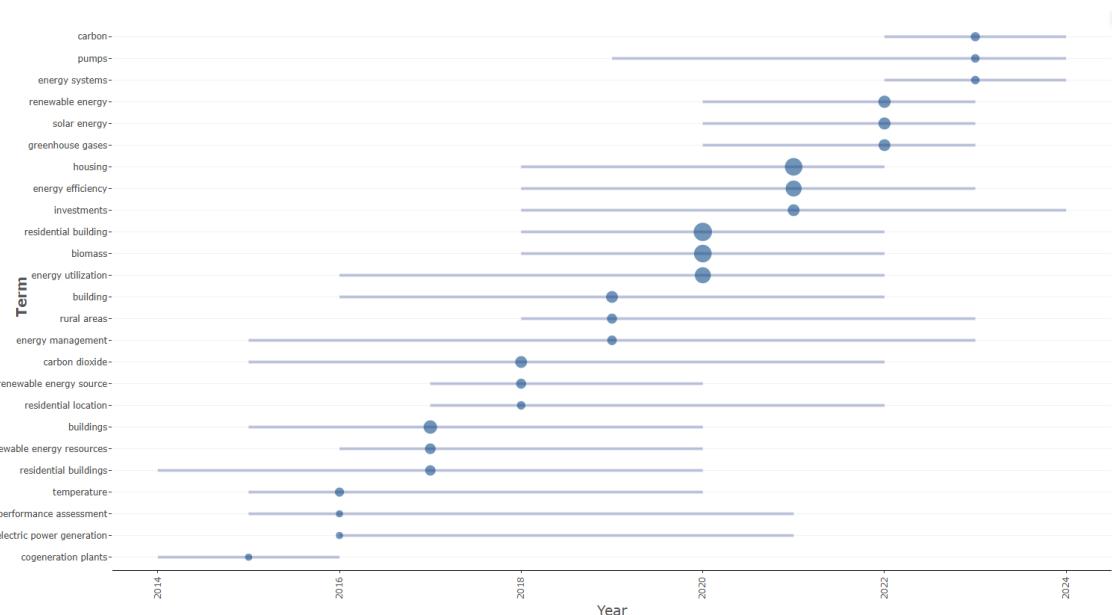


Figure 6. Temporal evolution of research keywords in of biomass materials in residential building construction (2014–2024)

In early 2014 to 2017, research focused on technical issues such as "electric power generation", "performance assessment", and "residential buildings", which became the initial foundation for the topic of biomass in construction. Entering 2018 to 2020, diversification of themes began to emerge, such as "renewable energy resources", "residential location", and "carbon dioxide", signifying a shift towards sustainability and carbon emissions in the building context. Peaking in 2020 to 2023, research increasingly emphasized direct implementation in buildings, as evidenced by the intensity of keywords such as "biomass", "residential", and "greenhouse" building", "investments", "energy" efficiency", and "building." This indicates a focus on real-world applications and energy optimization in biomass-based residential buildings. Then, in the period from 2022 to 2024, new, more complex keywords emerged, such as "solar energy", "energy", and "energy efficiency" systems", and "greenhouse gases", demonstrating the integration of biomass technology with other renewable energy systems to address the challenges of the climate crisis and greater energy efficiency. The temporal evolution of these keywords demonstrates that biomass research in the residential building sector has evolved from initial technical issues to strategic applications integrated with renewable energy systems.

## Discussion

This study comprehensively examines the scientific trends and knowledge landscape related to the use of biomass materials in residential building construction through a bibliometric approach. Overall, the results indicate that this topic has experienced significant growth in the last decade. The annual growth rate of publications reached 9.04%, which is in line with the increasing global attention to sustainability and energy efficiency issues in the housing sector. This phenomenon aligns with Adeleke's findings. et al. (2021), who highlighted the important role of biomass in supporting sustainable buildings, especially due to its thermal and economic characteristics.

In the context of literature dissemination, most of the publications come from reputable journals such as *Energies*, *Renewable Energy*, and *Journal of Cleaner Production*. This reflects that biomass research is not only relevant at the local level, but has become part of the global scientific discourse with high impact. *Journal of Cleaner Production* even has the highest number of citations (964), indicating its strategic role in disseminating biomass issues in low-carbon development.

In terms of scientific collaboration, the author network shows a highly collaborative pattern, with an average of 3.99 authors per document and contributions from 491 authors. Authors such as Luisa F. Cabeza from Xi'an Jiaotong Universities occupy a central position, with high productivity and broad citation impact. The existence of cross-border collaborations, as demonstrated by contributions from China and Italy, reflects the transnational nature of biomass research, as further reinforced by contributions from other European countries such as Sweden and Switzerland, which show the highest citation-per-article ratios. Furthermore, thematic analysis revealed that biomass research in residential buildings has evolved from basic themes such as *residential building* and *housing*, towards driving themes such as *carbon emission*, *renewable energy*, and *optimization*. These findings are supported by the research results of Fernández et al. (2024) and Zhao et al. (2023) who stated that biomass is not only an alternative material, but is an integral part of climate change mitigation strategies in future architectural designs.

Temporal trends also show a shift from technical topics towards strategic and systemic applications, with the emergence of keywords such as *solar energy*, *greenhouse gases* and *energy systems* in the 2022–2024 period. This shift demonstrates the integration of biomass into the broader context of the renewable energy transition. On the other hand, the findings of keywords such as *retrofitting* and *economic analysis* indicates that economic studies and investment efficiency are becoming new concerns in this field.

Finally, citation analysis shows that seminal works such as Ürge-Vorsatz et al. (2015) and Su et al. (2018) is a key reference in developing the theoretical foundations and practices of biomass. Local references also show a focus on building energy efficiency and hybrid biomass systems, as demonstrated by Ogunjuyigbe. et al. (2018), which strengthens the contextual approach in developing locally based solutions.

## Conclusion

This study shows that the topic of *biomass materials in residential building Construction engineering* has experienced significant quantitative and qualitative growth over the past decade. A consistent increase in publications, contributions from leading journals, and cross-border collaborations indicate that this field is

increasingly strategic in supporting sustainability and carbon emission reduction. Thematic analysis indicates a shift in research from basic issues to integrative approaches, such as energy optimization, retrofit strategies, and biomass integration with renewable energy systems. Furthermore, the presence of high-impact references confirms that this field is supported by a solid and dynamically developing literature. Overall, these results not only map scientific developments in the field of building biomass, but also open up opportunities for further research related to technical, economic, and policy aspects in the context of low-carbon development, especially in regions with abundant local resources such as the 3T regions in Indonesia.

## Scientific Ethics Declaration

\* The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

## Conflict of Interest

\* The authors declare that they have no conflicts of interest

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