



## RESEARCH ON THE TREND OF SUSTAINABLE ARCHITECTURE: A BIBLIOMETRIC ANALYSIS ON THE HOUSING, THERMAL COMFORT, AND FAÇADE

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**Abstract:** Sustainable architecture plays a crucial role in minimizing environmental impact and enhancing energy efficiency in buildings. This study aims to explore research trends in sustainable architecture, particularly in housing, thermal comfort, and façade design, using bibliometric analysis with VOSviewer. The data were retrieved from the leading academic databases (Scopus). The analysis was conducted on the study maps keyword relationships, author collaborations, and institutional influences through co-occurrence network. The findings highlighted a growing emphasis on passive design strategies, innovative façade technologies, and adaptive thermal comfort models to promote sustainability in housing. Further analysis identified the cluster key themes involved thermal comfort, housing, architectural design, energy efficiency, and thermal insulation. This research offers valuable insights to develop the sustainable architecture, providing a useful reference for architects, policymakers, and researchers looking to enhance energi-efficient housing designs yet still prioritizing occupant comfort.

**Keyword:** bibliometric analysis, façade design, housing building, sustainable architecture, thermal comfort

**Abstrak:** Arsitektur berkelanjutan memainkan peran penting dalam meminimalkan dampak lingkungan dan meningkatkan efisiensi energi pada bangunan. Penelitian ini bertujuan untuk mengeksplorasi tren penelitian dalam arsitektur berkelanjutan, khususnya pada bidang perumahan, kenyamanan termal, dan desain fasad, menggunakan analisis bibliometrik dengan VOSviewer. Data diperoleh dari basis data akademik terkemuka (Scopus). Analisis dilakukan untuk memetakan hubungan kata kunci, kolaborasi penulis, dan pengaruh institusional melalui jaringan ko-okurensi. Temuan penelitian menyoroti semakin besarnya penekanan pada strategi desain pasif, teknologi fasad inovatif, dan model kenyamanan termal adaptif untuk mendorong keberlanjutan dalam perumahan. Analisis lebih lanjut mengidentifikasi tema-tema utama kluster yang meliputi kenyamanan termal, perumahan, desain arsitektur, efisiensi energi, dan insulasi termal. Penelitian ini memberikan wawasan berharga untuk pengembangan arsitektur berkelanjutan, sekaligus menjadi referensi yang berguna bagi para arsitek, pembuat kebijakan, dan peneliti yang ingin meningkatkan desain perumahan hemat energi dengan tetap mengutamakan kenyamanan penghuni.

**Kata Kunci:** analisis bibliometrik, desain fasad, bangunan perumahan, arsitektur berkelanjutan, kenyamanan termal

### INTRODUCTION

The growing demand for sustainable development in the built environment has made energy-efficient and housing concept that environmentally friendly were more important than ever. Among the many aspects of sustainability, thermal comfort and façade design play a key role in improving energy performance and enhancing occupant well-being (Aksamija, 2013). A well-designed façade helps reduce heat gain, promotes natural ventilation, and lowers reliance on mechanical cooling systems (Du & Chen, 2011). At the same time, achieving optimal thermal comfort in housing requires a holistic approach that integrated passive design strategies, innovative materials, and

adaptive ventilation techniques (Stavrakakis et al., 2012). As the outermost layer of a building, the façade serves as a critical interface between indoor and outdoor environments, significantly influencing thermal regulation and natural daylight access (Garfield, 2006). Researchers have explored various advanced façade strategies, such as double-skin façades, dynamic shading systems, and high-performance glazing, to improve energy efficiency and occupant comfort (Givoni, 1998). However, balancing aesthetics, energy performance, and cost-effectiveness remains challenging, particularly in high-density housing, where space, and resource constraints must be carefully managed (Hyde, 2008).

Despite the increasing focus on sustainable architecture, specific studies examining the relationship between thermal comfort, façade design, and housing are still relatively limited (Katafygiotou & Serghides, 2014). The adoption of innovative façade technologies is often hindered by economic constraints, a lack of technical expertise, and inadequate policy frameworks especially in developing regions (Moed, 2005). Understanding the latest research trends in this field is essential for guiding future architectural innovations and policy decisions (Olgyay et al., 2015). To address this gap, this study employs bibliometric analysis to examine research trends in thermal comfort, façade design, and housing buildings (Prianto & Depecker, 2002). Using data from reputable academic databases, it visualizes research networks, identifies key thematic clusters, and highlights emerging topics in the field. The findings provide valuable insights for architects, engineers, and policymakers aiming to enhance sustainability in residential architecture (Ratti et al., 2005).

## METHODS AND MATERIAL

This study used bibliometric analysis to explore the research landscape and identify knowledge trends in sustainable architecture, with a focus on thermal comfort, façade design, and housings (Shah et al., 2008). This method helped uncover patterns in research, including geographical distribution, leading authors, institutional affiliations, and keyword relationships within the field (van Eck & Waltman, 2010). In order to gather relevant data, the study relied on Scopus, one of the most comprehensive academic databases, which provides access to citation records, abstracts, and keywords. This study used bibliometric analysis to explore the research landscape and identify knowledge trends in sustainable architecture, with a focus on thermal comfort, façade design, and housings (Shah et al., 2008). This method helped to uncover patterns in research, including geographical distribution, leading authors, institutional affiliations, and keyword relationships within the field (van Eck & Waltman, 2010).

To ensure a clear and meaningful bibliometric analysis, several filters were applied to refine the data selection process. First, specific keywords such as thermal comfort, facade, and housing were used to narrow down the investigation and focused on the studies directly related to the research topic. The time frame was set between 2020 and 2025, ensuring that only recent and relevant studies used in this study. The subject area was also considered, with the limited search to engineering, energy, and environmental sciences that closely aligned with the focus of the study. Additionally, only final and officially published were selected, excluding preprints or unpublished research to maintain credibility. To ensure consistency and accessibility, the study focused solely on English-language publications, as English is the dominant language in high-impact academic journals. Finally, the relevant

keyword helped to verify that the selected studies accommodated the essential terms i.e. housing, thermal comfort, energy efficiency, architectural design, and residential buildings. These carefully applied filters helped to ensure that the collected data was focused, reliable, and aligned with the objectives of the studies. The full procedure for conducting this study can be seen in **Table 1**.

A preliminary investigation was conducted using three key terms i.e. thermal comfort, façade, and housing. These keywords represented the fundamental aspects of sustainable architecture and urban environmental performance. As per March 4, 2025, the Scopus search retrieved 41 relevant documents that published between 2020 and 2025, covering various disciplines and publication types. To ensure the analysis was conducted properly, specific exclusion criterias were applied before exporting the data for further meta-analysis. The final dataset was exported in CSV format, including citation information, abstracts, and keywords. The bibliometric analysis was conducted using **VOSviewer**.

**Table 1.** Filter of data mining

Limitation criteria	Limitation	Information	Result
L1: Search Keyword	Thermal Comfort Façade Housing	-	137
L2: Year	2020-2025	Completed year	62
L3: Subject area	Engineering Energy Environmental science	Correlation to the keywords	53
L4: Publication stage	Final	Final and officially published	53
L5: Language	English	The standard language for high impact journal	50
L6: Keywords	Housing Thermal comfort Energy efficiency Architectural design Residential building	Relevant to research focus	41

## RESULT AND DISCUSSION

### 1. Publications: year, subjects, & publishers

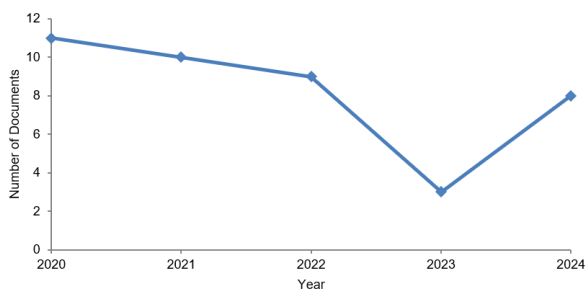
This study analyzed the total number of publications to identify trends in annual

distribution and participation across different subject areas. This analysis utilized the Scopus program to generate graphs and charts based on annual publication trends, subject area contributions, and the most active journals related to the keywords.

According to the annual trends from 2020 to 2022, the number of publications slightly declined from approximately 11 documents in 2020 to 9 in 2022. However, a significant decrease occurred in 2023, with only about 3 publications. Despite this decline, the number of publications increased in 2024 with 8 documents, indicating an improvement in this area. The average number of publications per year is **8 documents**, reflecting some fluctuations but an overall continued engagement with the topic. **The results of this analysis are shown in Figure 1.**

In terms of subject areas, the majority of publications decreased under Engineering area at 37.2%, followed by Environmental Science area at 17.9%, and Energy area at 10.3%. Other subject areas, such as Computer Science, Social Sciences, and Materials Science, contributed to a smaller proportion of the publications. Regarding the most active journals, Energy and Buildings and Buildings had the highest number of publications, with 3 documents each. **These results are shown in Table 2.**

Meanwhile, journals such as Solar Energy, PLEA 2020 Conference on Passive and Low Energy Architecture Planning Post Carbon Cities Proceedings, and IOP Conference Series Earth and Environmental Science had 2 publications each. From this analysis, it can be concluded that research related to engineering and environmental science continues to dominate publications, despite fluctuations in annual trends. The decline in 2023 may have been influenced by the external factors, however the increase in 2024 showed the significant interest and engagement in this research area. **This information is detailed in Table 3.**



**Figure 1.** Documents by year

**Table 2.** The percentage of documents by subject area

Subject	Percentage
Engineering	37.2
Environmental	17.9
Energy	10.3
Computer sciences	7.7
Social sciences	6.4

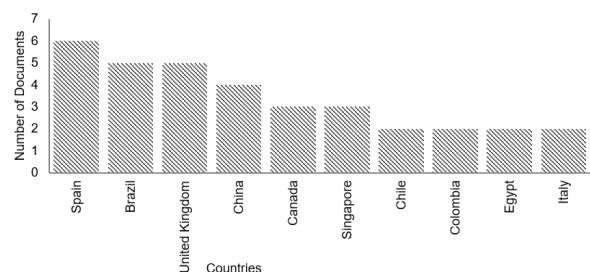
Material sciences	5.1
Chemical engineering	3.8
Earth and planetary sciences	3.8
Arts and humanities	2.6
Mathematic	2.6
Other	2.6

**Table 3.** The most published journals/proceedings

Journal/Proceeding Name	Total documents
Energy And Buildings	3
Buildings	3
Solar Energy	2
PLEA 2020 35th PLEA Conference on Passive and Low Energy Architecture Planning Post Carbon Cities Proceedings	2
IOP Conference Series Earth and Environmental Science	2
Architectural Science Review	2
Wit Transactions on The Built Environment	1
Sustainable Cities and Society	1

**2. Publications: year, subjects, & publishers**

European countries played a dominant role in the research, contributing the highest number of documents in terms of country-based distribution. Spain leads as the most involved country, followed by Brazil and the United Kingdom. China and Canada are the only non-European countries that belong to the top five. Spain recorded the highest involvement, with approximately six research documents. Meta-analysis using network visualization presented the relationship between countries involved in the research. The United Kingdom appeared as a central node, indicating a strong research link with multiple countries, including Ecuador, the United States, and Chile. These results are displayed in **Figure 2.**



**Figure 2.** Documents by country

The visualization reflected a broad involvement of research collaborations across different continents. The time-based visualization illustrated the research trends from 2020 to 2023. The colour gradient represented the timeline, where earlier research contributions were depicted in blue, while more recent studies

are in yellow. The United Kingdom, Ecuador, and the United States contributed to earlier research, and Canada and Italy emerged in the later period. The findings indicated a progressive expansion of research collaboration over time. These are presented in **Figure 3**.



**Figure 3.** VOSViewer analysis countries involvement during the period 2020-2025

## CONCLUSION

This bibliometric analysis highlighted the trends in the sustainable architecture research, focusing on housing buildings, thermal comfort, and façade design. The study found out that passive design strategies, advance façade technologies, and adaptive thermal comfort models have increased significantly. Although there was a decrease in the number of research publications in 2023, the field showed signs of recovery in 2024, emphasizing its continued relevance. The keyword analysis revealed five key thematic clusters i.e. ventilation, thermal performance, housing, thermal comfort, and air quality. These clusters demonstrated the connection of various research areas, stressing the importance of an integrated approach to sustainable building design. Geographically, European countries, particularly Spain, the United Kingdom, and Brazil have been at the lead of the most research contributions. However, international collaboration is expanding as reflected in the co-authorship networks involving multiple regions.

Overall, this study provides valuable insights into the current state of sustainable architecture research. It serves as the literature for architects, engineers, and policymakers seeking to improve energy efficiency, occupant comfort, and environmental sustainability in residential buildings. Future studies should address existing research gaps, particularly in the practical implementation of innovative façade technologies in developing regions.

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