


An Overview of the Effects of Passive Solar Strategies on Thermal Comfort

Joy Nanlop Uwa¹, Assos. Prof. Dr. Parastoo Pourvahidi²

Faculty of Fine Arts, Design and Architecture, Cyprus International University, Nicosia 99258, Cyprus^{1&2}

E-mail¹: nanlop55@gmail.com, E-mail²: ppourvahidi@ciu.edu.tr

ABSTRACT

The paper presents the impact of passive solar strategies on residential buildings concerning the thermal comfort factor. This study focuses on passive solar design elements like orientation, shading, and thermal mass to offer improved energy efficiency and occupant comfort. With a global natural gas crisis looming, interest in alternative heating and cooling is surging. With the growing concern of reducing the energy use by buildings while maintaining proper thermal comfort, both in cold and hot climates, the interest shifts to passive solar strategies. In this view, 547 publications have been analysed to reveal knowledge gaps and trends in the research. The bibliographic and thematic analysis techniques identified some approaches to passive solar design but no dominant method. Further, the study found under-researched areas within themes that appeared established. The authors have finally concluded with calls for further research and collaboration across institutions and nations to address these gaps and develop effective passive solar strategies. These findings contribute to sustainable architecture by pointing out the pros of applying passive solar strategies to reduce heating and cooling loads. In this respect, this was an original approach since it brought both quantitative and qualitative data together to measure thermal comfort. This is further underpinned by raising the need for energy-efficient building designs as measures toward mitigating climate change impacts.

JOURNAL OF MEDITERRANEAN CITIES (2024), 4(1), 25-48

https://doi.org/10.38027/mediterranean-cities_vol4no1_2

ARTICLE INFO:

Article history:

Received: July 06 2024

Revised: August 11 2024

Accepted: September 09 2024

Available online: Oct. 12 2024

Keywords:

Sustainable Energy; Passive Solar Strategies; Future Initiatives; Interdisciplinary Collaborations

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license



Journal of Mediterranean Cities stays neutral with regards to jurisdictional claims in published maps and institutional affiliations

Copyright ©2024 by Joy Nanlop Uwa, Assos. Prof. Dr. Parastoo Pourvahidi

www.mediterranean-cities.com

1. Introduction

Since most people spend 90% of their time indoors and rely on mechanical air conditioning and heating, buildings are now the world's biggest energy consumers (Cao, Dai and Liu 2016). Over 40% of all energy used worldwide and over 30% of all CO₂ emissions are generated by buildings, which consume a considerable portion of this energy (Yang, Yan and Lam 2014). Architecture must incorporate sustainable design methods due to increased energy usage and environmental concerns, a promising method to improve indoor thermal comfort (Gou, et al. 2018). A special focus is placed on ventilation approaches that use air and other renewable energy sources as ambient energy, as well as how they interact with heating and cooling systems (Omer 2008). Reducing dependency on mechanical heating and cooling systems has emerged among these strategies: passive solar design. By

Corresponding Author:

Joy Nanlop Uwa

Faculty of Fine Arts, Design and Architecture, Cyprus International University, Nicosia 99258, Cyprus

E-mail: nanlop55@gmail.com

How to cite this article:

Uwa, J. N., & Pourvahidi, P. (2024). An Overview of the Effects of Passive Solar Strategies on Thermal Comfort. 4(1), 25-48. doi:

https://doi.org/10.38027/mediterranean-cities_vol4no1_2

reducing power consumption, passive design is a strategy that can lower the demand for energy in buildings.

The capacity of passive solar strategies to offer long-term and affordable solutions for indoor thermal comfort has driven them to gain increasing popularity. This is accomplished by maximising heat loss through the use of the building's design, orientation, and materials. Its efficiency can be greatly influenced by climatic factors and architectural concerns, but it can increase indoor thermal comfort and lower energy usage in buildings. Designers of buildings can maximise the use of passive solar strategies to obtain the best thermal comfort and efficiency in a variety of climatic conditions by carefully evaluating a range of elements and using computer modelling tools. For instance, a study (Tawil, et al. 2018) carried out in Libya showed how passive heating and high thermal mass with passive cooling might provide indoor thermal comfort throughout the nation, avoiding the need for active solar or conventional heating and equipment. Grid energy management can also benefit from passive solar strategies like collector-storage wall systems using phase-change materials. Traditional architecture also offers inspiration for passive solar strategies, especially in tropical climates where traditional houses utilise natural lighting and ventilation to achieve indoor thermal comfort. Additionally, the effectiveness of passive solar strategy has been proven in numerous locations throughout the globe. Passive solar strategies provide a more natural and peaceful indoor thermal environment and save electricity.

The study's main aim is to determine the passive solar strategies for influencing residential building thermal comfort. The variables of passive solar design, like orientation analysis, shading, and thermal mass, are considered to explain their effect on indoor thermal conditions. The objective is, therefore, how effective the strategies would be in enhancing thermal comfort while reducing energy consumption for heating and cooling.

The present study is conducted with the notion of alleviating the growing energy use in residential buildings. Since climate change has turned into an acute global challenge, there is a serious urgent need for sustainable building practices that improve the thermal comfort class while reducing energy use. This research work will assess how effective passive solar design strategies are in improving thermal comfort and energy performance in a building. The research questions, therefore, are geared toward establishing major passive solar design elements that provide a most important contribution to thermal comfort and energy efficiency. This study, therefore, provides significant insights—actionable for architects, builders, and policymakers. Some unique points of this research are as follows:

1. Latest and Wide Time Range: The study was founded on a period of the last 40 years; hence, from 1982 up to 2022, it is very broad and very recent but lacking in information from 2023.
2. Worldwide Overview: It contributes to the determination and evaluation of passive solar strategies and their efficiency in various parts of the globe. All of these categories are discussed in detail.
3. Systematic Classification: Systematic classification of factors and methods that were in use very frequently in passive solar strategies has been done. This classification is based on similarities and differences. It covers key elements and advantages. Current development status of the field was explored, whereby a table showing data gathered with features such as publication year, source, authors, type of publication, number of methods combined and used and the primary purpose either cooling or heating.
4. Identification of Potential Studies: Several potential studies on passive solar cooling and heating solutions were identified in the review, pointing out avenues of future research.
5. Bibliometric and Bibliographic Analysis: With its focus on bibliometric and bibliographic analysis, this paper locates the major contributors and co-citation, direct citation networks, and bibliographic coupling networks for assessing and analysing research activities that have been working effectively.

6. Thematic Review: The identification, and in-depth examination, of themes emerging from the literature was done with MaxQDA. This tended to bring greater clarity regarding the trends and themes dominant in the field.

1.1. Brief history of passive solar strategies and purpose

Recent years have seen a rise in the popularity of passive solar techniques as a practical means of achieving thermal comfort within buildings while consuming less energy. Utilising the sun's free heat and light to reduce the need for heating and cooling systems lowers energy costs and encourages more environmentally friendly building techniques. The climate in which they are employed can, however, affect how effective passive solar techniques are. Passive solar techniques in hot climates must be carefully planned to prevent overheating, whereas in cold climates they must be planned to optimise sun gain while avoiding heat loss (Stutz, et al. 2017). Passive solar methods are becoming more and more popular as a realistic way to achieve indoor thermal comfort while lowering energy usage in buildings. The effectiveness of the principles of passive solar design in terms of indoor thermal comfort has been examined in numerous studies (Huang, et al. 2007) (Hou, et al. 2021; 2020) (Zhao, et al. 2020) and has been applied to a variety of climates around the world. These studies demonstrate that passive solar techniques can considerably increase thermal comfort indoors, even in harsh climates. For instance, in a hot and humid area, passive solar techniques like shade, natural ventilation, and thermal mass can cut inside temperatures by up to 8°C compared to conventional structures. This strategy makes use of the sun's natural heat and light to cut down on the demand for heating and cooling systems, leading to lower energy costs and a more environmentally friendly structure. The climate in which passive solar techniques are used, however, can affect how effective they are. To prevent overheating in hot areas, passive solar methods must be carefully planned, whereas in cold climates, they must be planned to optimise solar gain while reducing heat loss (Stutz, et al. 2017).

Numerous studies have looked at the usefulness of passive solar design concepts in terms of indoor thermal comfort (Gou, et al. 2018) (Huang, et al. 2007) (Kapsis, Dermardiros and Athienitis 2015). Passive solar design principles have been used in numerous parts of the world with a variety of climatic conditions. These studies show that even in the most severe regions, passive solar techniques can greatly increase indoor thermal comfort. For instance, passive solar techniques like shading, natural ventilation, and thermal mass can lower indoor temperatures by up to 8°C as compared to traditional buildings in hot and humid conditions (Randjelovic, et al. 2021). To access solar radiation, though, some requirements must be met. For instance, the sun's position is influenced by the principles of building facades (solar altitude and azimuth), the slope and orientation of the site, any obstruction present on the site, and the potential for shadowing caused by obstructions outside the building (Lofabadi 2015).

Passive solar techniques can also help in cold climates to cut energy use and increase thermal comfort. For instance, a Canadian study indicated that a passive solar house maintains a more constant interior temperature while using 60% less energy to heat than a conventionally constructed house (Kapsis, Dermardiros and Athienitis 2015). Standard passive solar solutions for cold places include increasing solar gain through south-facing windows, storing heat through thermal mass, and reducing heat loss through insulation and airtightness (Marszal, et al. 2011). The effectiveness of passive solar methods can be affected by a variety of elements, including building orientation, shading, glazing characteristics, and ventilation, even if they have demonstrated potential in terms of improving thermal comfort indoors and reducing energy use (Ahmed, Kumar and Mottet 2021). For instance, a study carried out in Spain discovered that the effectiveness of passive solar solutions was greatly influenced by the orientation of the structure, with south-looking buildings performing noticeably better than those facing other directions (Sun, et al. 2020). Like how shading from nearby structures or vegetation can lessen the efficiency of passive solar techniques and raise the requirement for artificial heating and cooling, (Randjelovic, et al. 2021) shading from nearby structures and vegetation can also limit solar gain.

Building designers must carefully consider several aspects to enhance the efficiency of passive solar solutions, including the building's orientation, glazing characteristics, shading, thermal mass, and ventilation. The performance of various design options may be modelled using computer modelling tools, and passive solar techniques can be deployed more effectively in a variety of climatic situations. (Marszal, et al. 2011).

1.2. Passive Solar Strategies

According to the research, the idea of passive solar design can easily be incorporated into a house at the planning stage (Morrissey, Moore and Horne 2011). This was reflected in a good number of the publications analysed in the study, as captured in Figure 2. Several of the articles explored the tendency for future growth or further research. Passive solar building designs are gaining popularity to save energy and reduce the environmental effects of construction. According to Stevanović's (Stevanović 2013) examination of simulation-based optimisation research, sunspaces are among the passive solar design options that can successfully reduce a building's energy demand. The implementation of energy-efficient and affordable passive solar heating systems was examined using a variety of approaches and resources. A range of passive solar approaches have been explored in the study to maximize natural sunlight and manage solar gain through shadow. Improved building orientation, for example, and the addition of internal greenhouses or sunspaces have both been shown to be beneficial passive solar solutions for decreasing energy demand for heating while increasing solar heat. Passive solar design solutions, such as sunspaces, have proven to considerably cut building energy usage (Stevanović 2013). Furthermore, research on the influence of sunspaces on buildings has been underway for years, demonstrating their potential to lower the demand for heating energy and the use of fossil fuels.

The numerous passive solar techniques covered in the review may be classified into the following groups:

1.3. Passive Solar Cooling

1.3.1. Thermal Mass

It is best to shade all of the windows during the summer months with overhangs or other coverings like shading, shutters, and framework. A south-facing window with a sunshade that covers half of the window's height can screen summer sunrays while letting in winter sunrays when the sun is lower on the horizon at sunrise and sunset (Kuczyński, et al. 2021). Since the sun's angle is lower in the morning and afternoon, overhangs on windows facing east and west are less effective. Employing plants to provide shade or reducing the number of windows that face east and west can be effective for cooling. Generally speaking, one can use landscaping to block summertime heat gain (Zhang, He and Yang 2010).

1.3.2. Ventilation

Natural ventilation is effective in keeping indoor temperatures close to outdoor temperatures, making it a cooling method when indoor temperatures are equal to or higher than outdoor temperatures (Gross 2021). The most suitable natural ventilation strategy will depend on the current climate. In areas where the daytime wind blows, and daytime ventilation is advantageous, it is advisable to open windows on the sides under and opposite the building to ensure cross ventilation. During the design phase, windows should be installed on walls opposite the prevailing wind. Wing walls can improve ventilation by connecting windows to walls perpendicular to the prevailing wind. Strong vertical panels placed at right angles to the wall between the two windows can increase the natural wind speed by taking advantage of the pressure difference created by the wing walls.

1.3.3. Convective Cooling

Convective cooling is an ancient method used to bring cool nighttime air from the outside and expel hot interior air. High vents on the leeward side help escape hot air near the ceiling, while low vents on the windward side allow cool air to flow in (Ketwong, Deethayat and Kiatsiroat. 2021) In regions without consistent breezes, thermal chimneys can nonetheless accomplish convective cooling by creating a region of warm or hot air and include a high outer exhaust opening. Warm air is expelled from the building via the upper vent, while colder air is brought in through the lower vent. An illustration of this concept may be seen in a sunroom that is connected to the south side of a building and has vents at the top. In this setup, air is pulled from the main living area and then discharged via the upper vents. (Saraei and Moujaes 2021).

1.3.4. Shading

During the summer, it is best to darken all windows with curtains or other coverings such as blinds, shutters or nets. South-facing windows with half-height window shades block summer sunlight and allow winter sunlight to penetrate low on the horizon at sunrise and sunset. Due to the low angle of sunlight during morning and afternoon, projections on windows facing east and west are ineffective. Utilising vegetation for shading or decreasing the quantity of windows facing east and west to enhance cooling efficiency (Yao and Zheng 2017). In general, landscaping can be used to combat the summer heat.

1.4. Passive Solar Heating

1.4.1. Indirect Gain

The thermal body, positioned between the sun and the living area, captures solar radiation and transfers it to the living space. Indirect gain systems use around 30-45% of the solar energy that is absorbed by the glass adjacent to the thermal mass. A popular example is the Trombe wall, which incorporates a 15–18 cm --thick brick wall beneath a single or double layer of south-facing glass. The black outside surface collects solar heat, stores it in bits, and then distributes it into the living room. The heat is transported to the room when the internal temperature goes below the wall temperature (Pucar and Despic 2005). Operational vents at the top and bottom of the heat storage wall allow heat to bubble between the wall and glass and closing these vents at night guarantees radiant heat continues to warm the living space.

1.4.2. Direct Gain

The living space itself acts as a solar collector, absorbing and releasing heat. The south-facing glass allows solar energy to enter the home, interacting with the dark brick floors and walls. This material absorbs and stores solar heat during the day and transmits it indoors at night. The thermal mass also absorbs energy, which helps regulate the heat intensity during the day. Water tanks in living spaces can store heat, but their integration requires careful structural support. Direct-gain systems efficiently use 60–75% of solar energy through windows (Esen 2000). To optimise this system, it is very important to insulate the thermal mass from the outside temperature to prevent the spread of the received solar heat. Heat losses occur mainly when heating elements come into direct contact with the ground or when the outside air cools.

Optimising a building's orientation for optimal solar heat gain during the winter and less during the summer is crucial. This involves aligning the structure along the east-west axis, using southern exposure for windows, and placing shade components to minimise heat gains. Additionally, adding sunspaces or internal greenhouses can help capture and retain solar energy, reducing heating energy demand.

These areas serve as a barrier between the inside of the building and the outside, storing and slowly releasing heat back into the structure. (Stevanović 2013) The research discovered that sunspaces were beneficial in lowering energy usage in buildings. Thermal mass materials like concrete or masonry help control indoor temperatures by absorbing and dissipating heat, eliminating the need for additional heating or cooling technology. Proper insulation and air sealing are crucial for maintaining acceptable interior temperatures and reducing energy losses. Shade mechanisms like blinds, louvres, and overhangs can also help decrease solar heat gains and glare, thereby significantly reducing energy use.

Numerous studies on passive solar design solutions have been undertaken, as represented in the review. Here are a couple of such examples:

- Researched and analysed simulation-based optimisation studies that sought to assess the efficiency of passive solar methods such as sunspaces in lowering energy consumption in buildings. This study aimed to discover significant metrics and variables that determine the performance of various techniques (Stevanović 2013).
- The European research project OFFICE (Optimisation of Facades for Integrated Concepts of Energy and Environment) (2008–2011) (He, et al. 2021) investigated several techniques and technologies for implementing passive solar heating systems that are both economical and energy-efficient in buildings. The goal of the study was to look at how modern materials, components, and technologies may improve energy performance.
- "Thermal Balance for Efficient Heating and Cooling" looks at numerous passive solar design solutions, such as properly designed windows, walls, and other components, as well as the usage of thermal storage walls and vented Trombe walls (Athienitis, et al. 2015).
- Released "The Solar House: Passive Heating and Cooling," a book that explores the basics of passive solar architecture and gives in-depth research and case studies on successful passive solar projects (Chiras 2002).
- Undertook research to look at how occupant comfort and well-being were affected by passive solar design measures. It examines how thermal comfort, natural lighting, and ventilation affect a building's overall performance. These studies, along with others, show how progress and research are continuous (Arif, et al. 2016).

2. Methodology

The Framework for Literature/Thematic Review

The following processes constitute the framework utilised for reviewing the literature, as illustrated in Figure1.

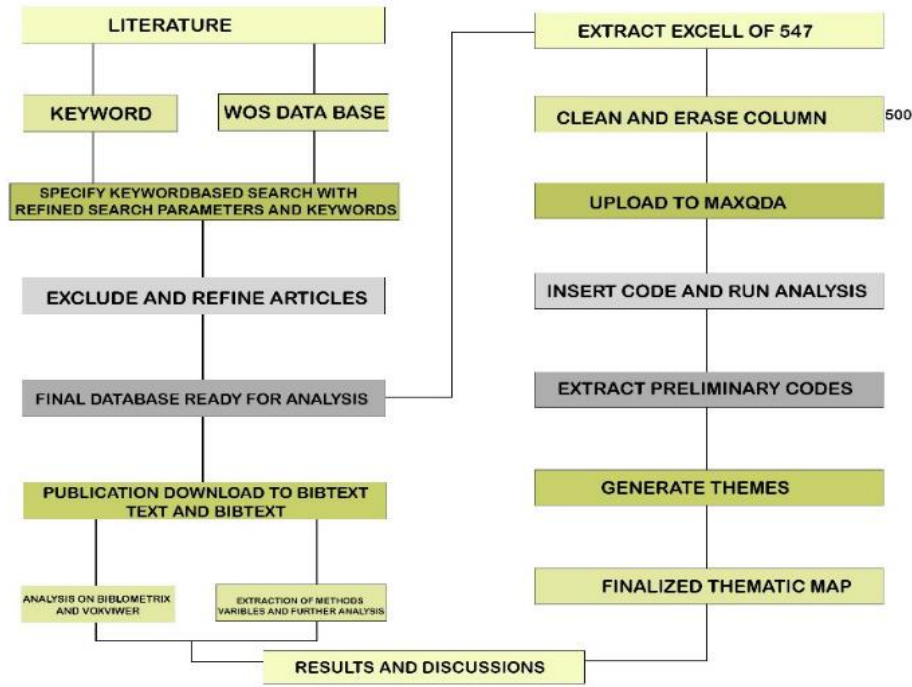


Figure 1. Methodology Framework (Source: Author)

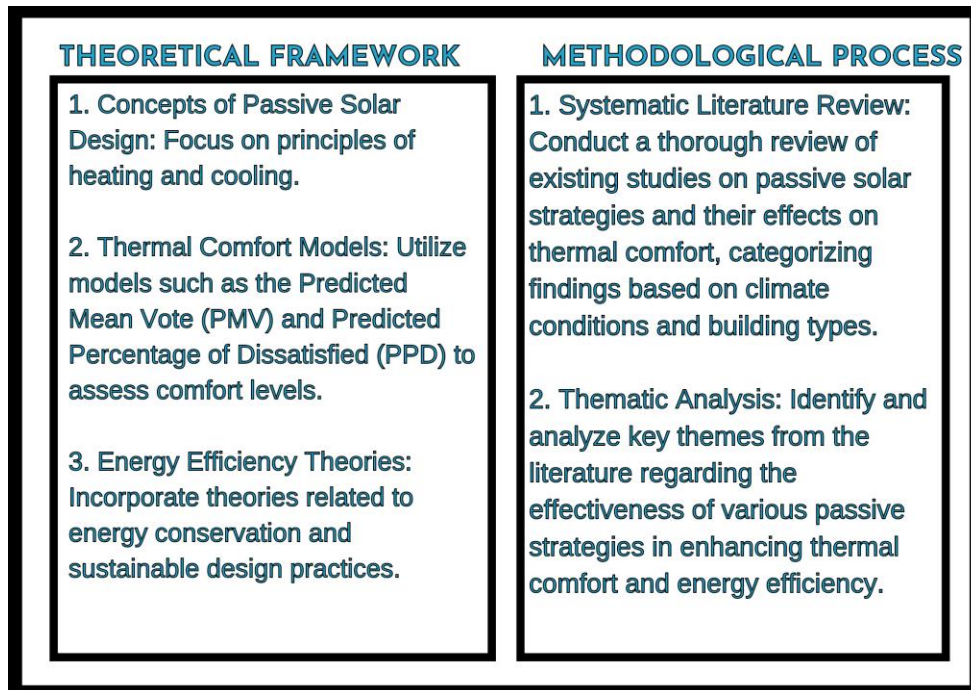


Figure 2. Theoretical Framework and Methodological Process (Source: Author)

A broad keyword search using the Web of Science database was performed to identify the most pertinent sources, conduct a more focused keyword search using bullions to refine the expected results and ensure a more precise search criterion. A more precise keyword will help identify the most relevant resources; conduct a more focused, refined search. The final list of sources was assembled using the following criteria: The practice of using passive solar techniques to cool, heat, or provide thermal comfort in specified climates or various/different temperature zones. A set of standards was developed to distinguish between the use of passive solar for heating and cooling. Analysing sources in-depth and extracting data that is pertinent to thermal comfort, passive solar techniques, and the qualities mentioned in the data collection section. Descriptive analysis was performed on all the data. To discover bibliometric networks, a bibliometric and biographic study of sources mentioned in the Web of Science was conducted. A more detailed cleaning of the data on Excel was done, bringing the total number of papers ready for thematic review to 500, ready for import on MaxQDA. Codes within MaxQDA were created to represent key themes and patterns identified in the literature. Descriptive analysis was performed on all collected data, providing an overview of the characteristics, trends, and patterns identified within the literature. Discussions (findings, interpretation, implications for future research, ideas for further research, etc.). Integrating insights from bibliometric analysis with RStudio and VOS Viewer and the thematic review within MaxQDA enriched the overall depth of the discussions.

The resulting measures or metrics in bibliometrics are often counts of the observed frequency of events of a given type, which, when expressed as ratios of the total number of recorded events, may be regarded as probabilities of occurrences (Borgman and Furner 2002). This strategy is used to evaluate the most cited sources, analyze research innovations, and identify journals with the most published work in a specific field of study. For this study, bibliometric analysis helped the assessment of literature by identifying collaboration in research, citation analysis, and how far research in this field has progressed, among other things see Figure 2. Co-authorship, direct citation, keyword occurrence network, and bibliographic coupling are examples of parameters. The software bibliometrix (version 4.2.2) and VOS viewer (version 1.6.19) were used to evaluate the bibliometric investigation. The analytical results contributed to the data collected, which was then included in the findings.

2.1. Alternatives Thematic Review

A thorough examination of the literature within a particular topic or conceptual framework is what a thematic review entails. Finding and examining patterns of meaning in text data is the process of thematic analysis, a qualitative research technique (Boyatzis 1998, Braun and Clarke 2006, Guest, MacQueen and Namey 2011). Numerous techniques, including theme mapping, memo writing, and coding, can be used to accomplish this (Braun and Clarke 2006). One piece of software that can help with thematic analysis is called MaxQDA. According to (Braun and Clarke 2006), it offers a range of tools for organising and evaluating text material, such as note writing, theme mapping, and coding. Identifying and analysing themes in a text dataset is part of the process of doing a thematic review with MaxQDA Figure 3. The following steps are usually involved in the process:

Data import: The text data must first be imported into MaxQDA. There are several ways to accomplish this, including importing a CSV file, copying and pasting the data into a text box, or using a data-gathering tool that exports to MaxQDA. However, in this particular scenario, an Excel file was imported.

Coding: Coding the text data is the next stage. Coding is the process of giving labels to text passages that illustrate various topics. Numerous coding techniques, including inductive, deductive, and hybrid coding, are available for usage (Braun and Clarke 2006).

Memo writing: Making notes about the coded data is the process of composing a memo. Memos are useful for jotting down ideas, observations, and analyses of the data.

The technique of graphically expressing the coded data is known as "thematic mapping." Numerous techniques, including the creation of these networks, thematic maps, and thematic trees, can be used to accomplish this (Braun and Clarke 2006).

Interpretation: Understanding the topic's findings is the last stage. This entails formulating judgements based on the data and establishing links with the larger body of literature.

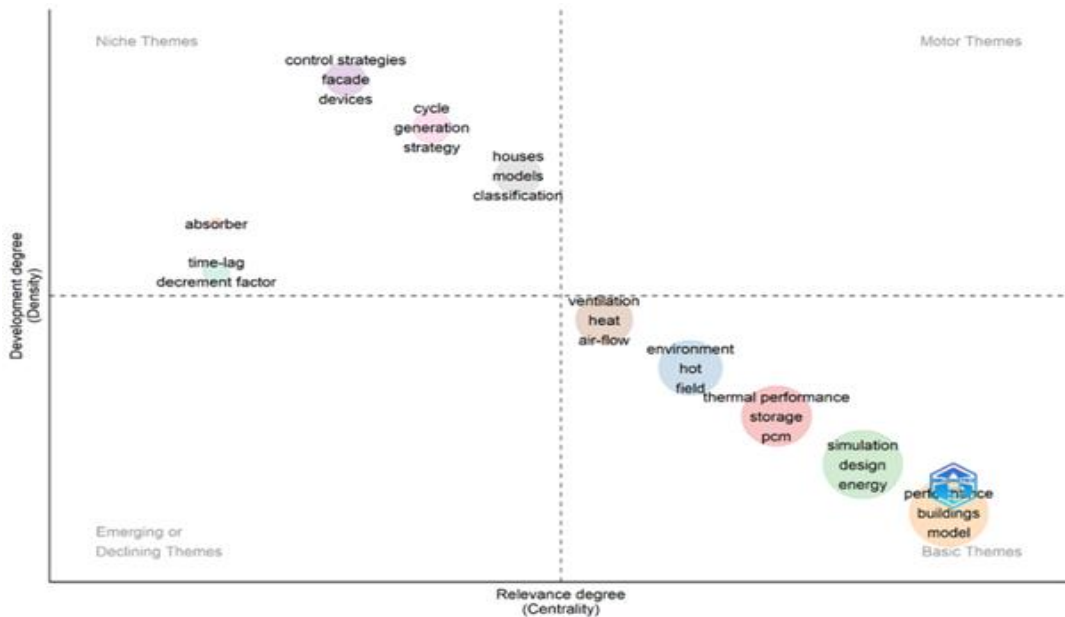


Figure 3. Thematic Map (Source: Author)

2.2. Data collection

The primary publishing source was determined to be the Web of Science (WoS) database. From general to specific, the data was gathered in that sequence. All languages and documents from the Web of Science's history (up to 2022) were included in the search. A broad keyword search produced a lengthy list of 10692 articles. We reached 10547 items after 2023 was removed. 8040 articles were offered in total to refine it. The final filtering resulted in a specific list of 1426 publications from the Web of Science. The articles underwent a more thorough cleaning process to remove irrelevant ones and ensure that only articles closely related to the fields were left. This decreased the overall number of papers used for the analysis to 555. However, the final list consisted of 547 documents, which were used to run the bibliometric analysis. Furthermore, the data in Excel format was further streamed to a total of 500 articles, which were used for the thematic analysis. To gather the most recent findings, a survey of the scholarly literature from 1982 onward was conducted. In the final list, more than 65% of the publications were published after 2015. The timeline of publication, as captured in Figure 4, depicts the total number of publications considered in the study from the graph, there has been an increasing trend up until 2015 and 2017, a noticeable decline in 2018, and an even lower decline in 2022. Several factors might have contributed to the decline of the research into passive solar strategies and their implementation from 2018 to 2022. Economic priority changes may have reduced the investment in sustainable building research during periods of financial instability and shifted funds to more immediate concerns. Changes in technology for alternative solutions, like advanced photovoltaics, battery storage, or active solar systems, could have eclipsed passive solar strategies, focusing attention and funding on their perceived efficiency. It has probably seen a decline because of changes in government policies and building codes, as well as a shift in the market to faster and more inexpensive construction methods. In addition, funding research into other pressing issues or new technologies might have been realigned. Global events, such as the COVID-19 pandemic, could have relocated research efforts into health-related areas from studies on passive solar strategies. The field perhaps reached a saturation point beyond

which major discoveries were made and published; research activity then began to naturally decrease as the field matured. All these factors call for attention so that interest and investment in passive solar strategies can be re-awakened, stressing their place as key players in sustainable building practices for energy efficiency by offering real-life experiences in their applicability and practical advantages.

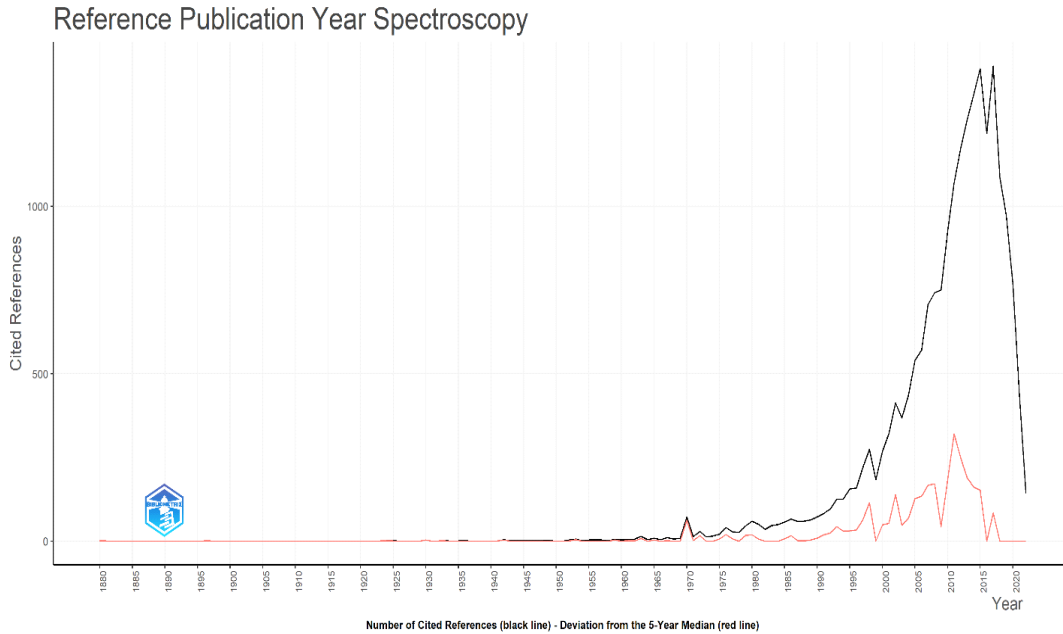


Figure 4. Timeline Publication (Source: Author)

3. Results

3.1. Bibliometrics Analysis

A well-liked and precise method for analysing and understanding a vast amount of scientific data is bibliometric analysis. It enables us to highlight the boundaries of an area and explore the complex details of its evolutionary history. In recent years, bibliometric analysis has grown in popularity in the scholarly community (Donthu, et al. 2021). According to (Godin 2006), bibliometrics was originally addressed in the 1950s, showing that the approach is not new. The growth of scientific research is particularly related to the proliferation of bibliometrics-based publications, which has increased over time, with an average of 1021 articles during the last ten years. However, due to the complexity and impracticality of applying typical review techniques to large bibliographic databases.

It is noteworthy that the growth of scientific databases like Web of Science, PubMed, and Scopus has made it quite simple to obtain substantial amounts of bibliometric data, spurring an increase in bibliometric analysis interest among academics in recent years. Scientific databases as well as bibliometrics tools like R Studio, VOS Viewer and Leximancer are improving accessibility and broadening the field's appeal. The quantitative evaluation of bibliographic data is known as bibliometrics, and it is a field of library and information studies. The best outcomes of a set of bibliographic items are typically summarized using bibliometrics. Numerous bibliometric studies on a variety of topics are accessible in the literature. Bibliometric methodology is the practice of applying quantitative approaches to bibliometric data, such as units of publishing and citation (e.g., bibliometric analysis, and citation analysis).

Whereby the use of bibliometrics may be used for everything from assessing publications to examining cooperation trends to investigating the intellectual hierarchy of a study topic. In this instance, journals

may also reflect the research field. Journal reviews have been provided using the bibliometric technique. Now is the time to compare bibliometric analysis to other often employed review alternatives, like systematic literature reviews and meta-analyses (Ramos-Rodríguez and Ruíz-Navarro 2004). Meta-analysis and bibliometric analysis both rely on quantitative methods as opposed to systematic literature reviews that typically employ qualitative techniques and may be distorted by interpretation prejudice from academics with diverse backgrounds (Donthu, et al. 2021). Therefore, they can prevent or mitigate this prejudice.

In this study, bibliometric analysis was performed on the 547 WOS -referenced articles. To list the most important associations or authorities in the field of study, Figure 5 was created, showing the affiliations that the researchers are listed under. The organisation with the most publications is denoted by the affiliation with the longest stroke, and the circles next to it show the organisation's greatest impact (number of papers published). In addition, a list of the top 10 affiliations in the research region with the most publications was presented; the aforementioned ten affiliations are indicated on the map by signatures. The majority of the 547 publications (36 of them) were written by authors from Tianjin University in China, followed by Xi'an University of Architecture and Technology (34 publications) and Chongqing University of China (29) in that order. There is also a strong relationship between the various titles associated with the study area and the author affiliations and author countries this is well represented in Figure 4.

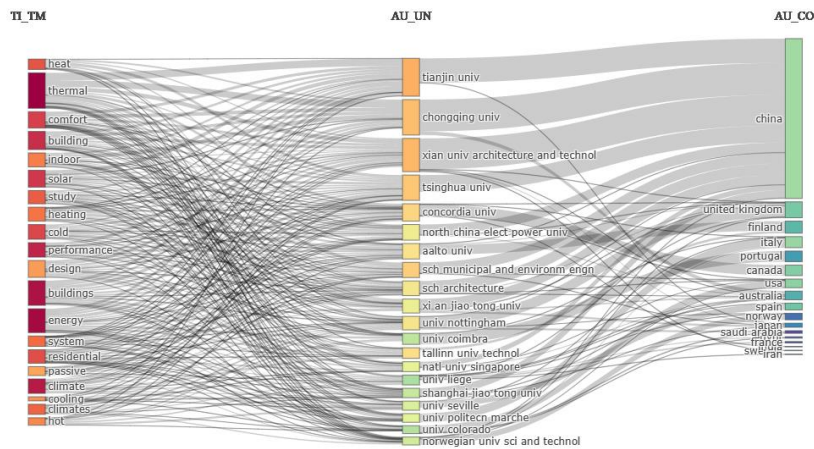


Figure 5. Three-field plot (Source: Author)

There were 15364 total citations for the publications that were considered in this study. The rest of the 547 articles have an average of roughly 28 citations on each one. Journals are also examined in terms of production over time. Determined in Figure 4 are a trend line and the years of production that were above the trend. With over 170 articles published in the Energy and Buildings journal in 2021, this shows a rise in interest in specific journals.

The data was acquired during the literature research, which served as a framework for additional quantitative analysis. The consolidated table (Table 1) has the 25 most cited articles. Providing details on the important characteristics of the research location, as well as the passive solar strategy used. The essence and differences of each approach utilized in the research field will be discussed in the last section. In addition, information on approach combinations, as well as a discussion of the merits and downsides of each methodology, will be presented.

Table 1. Showing the most cited publications in the review (Source: Author)

S/No	Name	Year	Title	Journal	No of Citations	References
1	Givoni. B	1992	Comfort, Climate analysis and building design guidelines	Energy and Buildings	266	(Givoni,1992)
2	Yu. W	2015	Application of Multi-Objective genetic algorithm to optimize energy efficiency and thermal comfort in building design	Energy and Buildings	249	(Yu,etal.2015)
3	Liu.Z	2017	Feasibility and performance study of the hybrid ground-source heat pump system for one office building in Chinese heating-dominated areas	Renewable Energy	166	(Liu, Xu and Zhai, et al. 2017)
4	Leckner.M	2011	Life cycle cost and energy analysis of a Net Zero energy house with solar combi system	Solar Energy	159	(Leckner and Zmeureanu 2011)
5	Jokisalo. J	2009	Building Leakage, infiltration and Energy Performance analyses for Finnish detached houses.	Building and Environment	146	(Jokisalo, et al. 2009)
6	Hobbi.A	2009	Optimal design of a forced circulation solar	Solar Energy	135	(Hobbi and Siddiqui 2009)

			water heating system for a residential unit in a cold climate using TRNSYS			
7	Rad. F.M	2013	Feasibility of combined solar thermal and ground source heat pump systems in cold climate, Canada	Energy and Buildings	133	(Rad, Fung and Leong 2013)
8	Emmi. G	2015	An analysis of solar-assisted ground source heat pumps in cold climates	Energy Conversion and Management	114	(Emmi, et al. 2015)
9	Maerefat.M	2010	Passive cooling of buildings by using integrated earth-to-air heat exchangers and solar chimneys	Renewal Energy	113	(Maerefat and Haghighi 2010)
10	Thalfeldt .M	2013	Façade design principles for nearly zero energy buildings in a cold climate	Energy and Buildings	112	(Thalfeldt, et al. 2013)
11	Pereira. L.D	2014	Assessment of indoor air quality and thermal comfort in Portuguese secondary classrooms: Methodology and results	Building and Environment	111	(Pereira, et al. 2014)
12	Papadopoulos.A.M	2002	Feasibility of Energy-saving renovation measures in	Energy and Buildings	111	(Papadopoulos, Theodosiou and Karatzas 2002)

			urban buildings. The impact of energy prices and the acceptable payback time criterion			
13	Gaurino.F	2017	PCM thermal storage design in buildings: Experimental studies and applications to solarium in cold climates	Applied Energy	109	(Guarino, et al. 2017)
14	Ozel.M	2013	Determination of optimum insulation thickness based on cooling transmission load for building walls in a hot climate	Energy Conversion and Management	107	(Ozel 2013)
15	Bakirci. K	2011	Energy analysis of solar-ground source heat pump system with vertical closed-loop for heating applications	Energy	107	(Bakirci, et al. 2011)
16	Zhang. A	2017	Optimization of an ultra-high CPV Casse-grain Koehler unit 200x Concentration Ratio	Energy Building	105	(Ferrer-Rodriguez,etal.2019)
17	Okeil.A	2010	A holistic approach to energy-efficient building forms	Energy and Buildings	105	(Okeil 2010)
18	Ismail. K.A. R	2008	Comparison between PCM-filled glass	Energy and Buildings	103	(Ismail, Salinas and Henriquez 2008)

			windows and absorbing gas-filled windows			
19	Freewan A.A. Y	2014	Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions	Solar Energy	102	(Freewan ,2014)
20	Stazi. F	2012	The behaviour of solar walls in residential buildings with different insulation levels:An Experimental and Numerical study	Energy and Buildings	99	(Stazi,Mastrucci and di Perna 2012)
21	Sokhansefat. T	2018	Thermo economic and environment analysis of solar flat plate and evacuated tube collectors in cold climatic conditions	Renewable Energy	98	(Sokhansefat, et al. 2018)
22	Fang. Z	2014	The effect of Building envelope insulation on cooling energy consumption in summer	Energy and Buildings	98	(Fang, et al. 2014)
23	Liu. Z	2015	Investigation on the feasibility and performance of ground source heat pump (GSHP) in three cities in cold climate zone, in	Renewable Energy	97	(Liu, Xu and Qian, et al. 2015)

China						
24	Susorova .I	2013	The effect of geometry factors on fenestration energy performance and energy savings in office buildings	Energy and Buildings	96	(Susorova, et al. 2013)
25	Nguyen .A.T	2011	An investigation on climate responsive design strategies of vernacular housing Vietnam	Building and Environment	94	(Nguyen, et al. 2011)

Visualisation of the publications and journals published and reflected in Table 1 was further clarified with bibliographic analysis.

3.2. Bibliographic Analysis

An efficient way of examining a variety of bibliometric networks is visualisation (Van Eck and Waltman 2014). In the next part, the results of the bibliographic analysis will also be reported. The bibliography reviews all co-citation networks of the researchers and serves as a presentation of co-citation analysis throughout this review. Figure 6. The top 103 writers out of 9980 who exceeded the threshold level with the minimum number of citations of 15 were utilized for visualization, and the total number of its nodes has been reduced to make it easier to understand. In the illustration, each circle stands for a different author. The circumference of a circle indicates how many citations an author has accumulated. According to co-citations, authors and journals that are positioned close to one another in the visualisation have a stronger relationship than those that are farther apart. In bibliography reviews, the researcher's co-citation network serves as a representation of the co-citation analysis conducted in this review. The circumference of a circle indicates how many citations an author has gathered. According to co-citations, authors and journals that are positioned close to one another in the visualization have a stronger relationship than those that are farther apart. Below is the list of the most cited author groups. 1. Givoni, B, (Givoni 1992). 2. Yu.W (Yu, et al. 2015). Figure 7. An analysis of documents with at least 10 citations generated figure 6 of a direct citation network which got the highest link of 197 by 386 of the 547 documents. It is very vital in determining an article's number of citations and it helps in the identification of key publications.

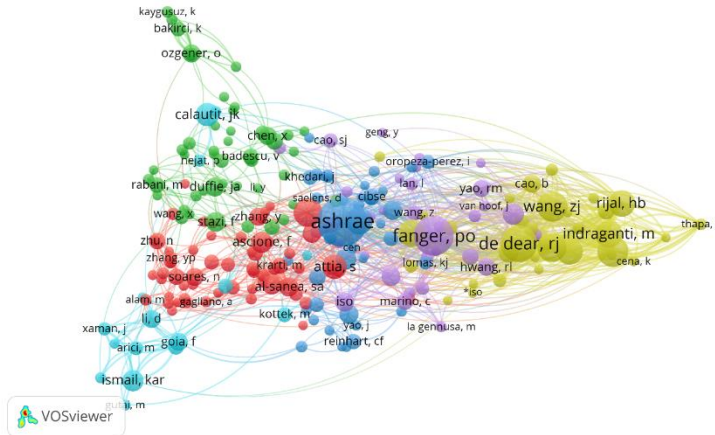


Figure 6. Direct citation network of articles (Source: Author)

The analysis of the keyword network of occurrences was conducted, to give a better insight into the words researchers use in the study field and to determine if there were new subtopics. Since keywords are related to the core content of the publications and analysis of keywords can identify critical results of studies related to passive solar strategies, figure 7 shows the overview of the keywords of a core data set of 2323 authors with a minimum number of 10 documents per author that meet the threshold.

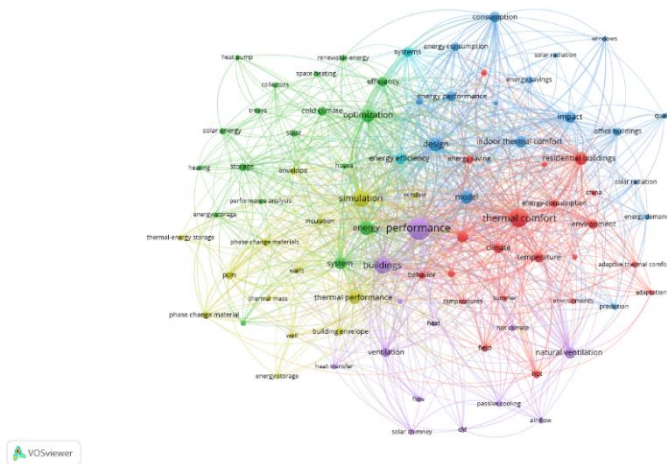


Figure 7. Co-occurrence network of keywords (Source: Author).

3.3. Thematic Analysis

To further identify patterns, trends, and recurring themes within the research area being studied and to synthesise and integrate knowledge generated from the WoS source, creating a coherent narrative that contributes to a deeper understanding of the subject. This is to further help identify gaps in existing literature, guide future investigations, and contribute to knowledge advancement in the study area. Thematic reviews inform research questions, guide methodological choices, and support evidence-based practice (Thomas and Harden 2008). They enhance literature review quality by offering a structured and systematic approach, ensuring comprehensive and well-organised reviews. They also

contribute to theory development by synthesising existing knowledge, proposing new perspectives, or modifying existing ones. They also facilitate effective communication and collaboration among researchers by providing a concise summary of existing knowledge. Overall, thematic reviews are essential for organising, synthesising, and evaluating existing knowledge, ultimately contributing to the advancement of research in a particular field.

3.4. Coding Structure

The initial code of 7, as captured in Figure 8, was applied, which yielded some considerable patterns tilting the data towards thermal comfort research. An additional 6 codes (building orientation, sunspaces, thermal mass materials, insulation and air sealing, shading, and optimisation) were added, making the total codes 13. However, the additional codes, all yielded zero appearance (see Fig.9 below), which means that none of the additional codes had an appearance of up to 3 in the 500 documents under analysis.



Figure 8. Cloud code (Source: Author)

As captured in Figure 9, with 230 occurrences, the term "simulation" is the most common one in the articles. This shows that in the subject of thermal comfort and passive solar strategies, simulation is an extensively employed methodology. With 207 documents, "cooling" is the second most common term. This suggests that to improve building energy efficiency and occupant comfort, researchers are actively investigating and debating cooling solutions. "Heating" and "thermal comfort" are mentioned somewhat less frequently, with 165 and 113 mentions, respectively. This implies that, although these subjects are significant, the present research focus may not be as focused on them. The terms "passive solar strategies" and "passive solar" occur just twelve and six times, respectively. This indicates that research on passive solar design principles is comparatively less common compared to other fields, highlighting a considerable gap in the literature.

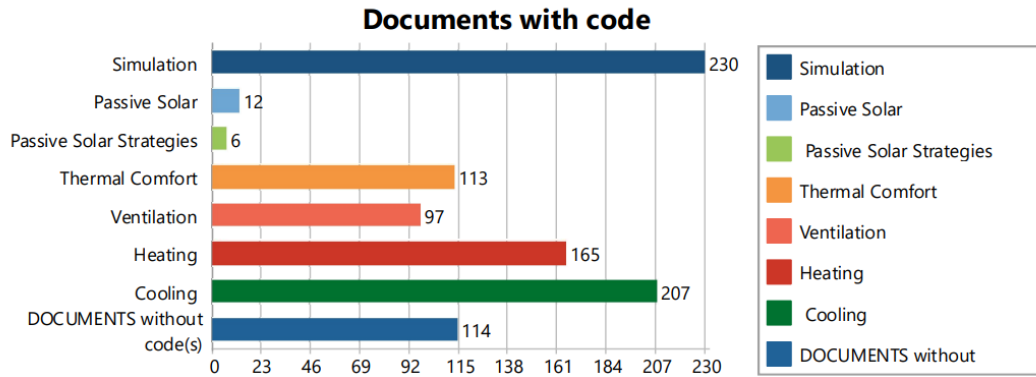


Figure 9. Showing documents with code appearance. (Source: Author)

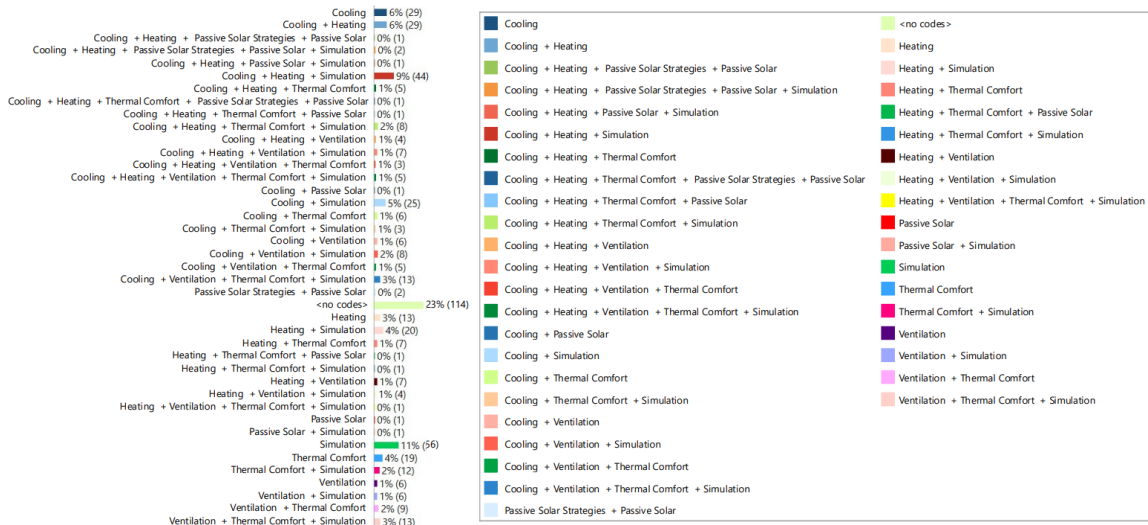


Figure 10. Showing documents with code appearance. (Source: Author)

In summary, taken as a whole, Figure 10. highlights the disparity in attention that various subtopics within the larger field of building energy efficiency receive. It implies that while thermal comfort, cooling, and simulations are extensively studied, passive solar solutions need further in-depth investigation.

4. Discussions

4.1. Results

Researchers work hard to publish articles and educate the public about the most recent scientific discoveries in various fields of interest as professors at universities. If there are more publications but no changes in the amount of energy used, what is wrong with this scenario? How can this be fixed? Since the United States and China consume more energy overall than any other nation, with China using the most electricity and the U.S. using the most oil, even though other elements affect a country's energy consumption-level of industrial development, geographic extent, style of living—the population has the greatest impact. The three most populous nations in the world are China, the United States, and third-placed India. Furthermore, the Joint Research Centre of the European Union estimates that total

worldwide CO₂ emissions rose from 34.1 GT in 2010 to an all-time high of 37.9 GT in 2019. Emissions decreased to 35.962 GT in 2020 as a result of the COVID-19 epidemic and the ensuing travel and transportation limitations, but it is anticipated that they will rise again once 2021 totals are available. With carbon dioxide emissions in 2020 totalling 11680 Mt (11.680 GT), China will be the world's highest CO₂ emitter. In 2020, this will account for slightly over 32% of global emissions. With 4.535 GT, or roughly 12.6% of the total global emissions, the United States produced the second-highest quantity of carbon emissions (Looney 2021). According to the above statistic, China has the biggest use of energy worldwide as well as the highest rate of publishing for passive solar technologies. Instead of the three universities, China also has the highest publishing rank. There is conflict as a result.

The results of this study provide a critical understanding of how passive solar strategies influence thermal comfort in residential buildings. The findings indicate that orientation, shading, and thermal mass play significant roles in regulating indoor temperatures and reducing reliance on mechanical heating and cooling systems. These results support the initial hypothesis that passive solar design can significantly enhance energy efficiency. The discussion also highlights the implications of these findings for sustainable building practices and policy-making. The functionality of the methodology was robust, employing both quantitative measurements and qualitative assessments to provide a holistic view of thermal comfort. Additionally, passive techniques like better window design that encourages natural ventilation and allows solar radiation to raise low temperatures in the winter can be used to maintain thermal comfort in residential structures. The thermal efficiency alternatives for buildings in various climatic settings have also been the subject of numerous studies. Passive solar design is a climate-sensitive strategy that emphasises the building's energy-saving component and incorporates design strategies to support thermal comfort in various climates. Despite the benefits of passive solar design techniques, based on the analysis, the field still has little research, showing that a lot needs to be done in that field of research.

4.2. Critical Review and Argument on the Results

The outcomes that emerge from the studies cited in the bibliography provided have different implications for the theoretical frameworks in which they engage, particularly those relating to renewable energy, energy efficiency, and the design of sustainable buildings. On the whole, results return a significant improvement in understanding the impact of variables on building energy performance and thermal comfort. For instance, in their study, Tudiwer and Korjenic 2017 demonstrated the huge impact of facade openings on interior temperature in buildings, resulting from the interaction of different climate zones. Thus, this outcome further substantiates the hypothesis that architectural design elements might turn into an essential share of passive solar heating and cooling strategies. Their approach to assessing different climatic zones adds strength to their findings, which suggest that localized architectural adjustments are needed to achieve optimal energy performance.

Wang et al. (2009) took into account the design process of zero-energy houses in the UK, and their results show that in the case of mixing energy-efficient technologies with renewable energy systems, zero-energy status can be achieved. Their case study approach did a very good job of demonstrating practical implementation and real-world challenges effectively, thus providing strong grounds for future research and policy development. Zhai and Previtali 2010 evaluated the energy performance of traditional vernacular architecture and concluded that traditional design elements offer superior thermal comfort and are often more energy-efficient than their modern counterparts. This forms part of the theoretical framework of learning from historical practices of buildings to come up with better modern sustainable design. Yang, Yan, and Lam 2014 were said to have given a holistic review of thermal comfort and its implication on building energy use. Their findings reflect a very important aspect of human comfort in the design of energy-efficient buildings, therefore corroborating the supposition that energy savings should not be at the expense of occupant comfort. Based on a detailed literature

review, subsequent analysis has shown that thermal comfort should be integrated into energy modelling frameworks.

4.3. Implications of the Results

These studies have a triple implication: first, they all reaffirm that building design elements, such as façade openings, thermal mass, and ventilation, are the real promoters of energy efficiency and comfort in a building. These results imply the need for architectural and engineering practices to seriously include climate-responsive design principles. Second, they underline the need for an integrated approach in sustainable building design—marrying technology with tradition. Studies in ancient vernacular architecture and zero energy house design indicate that fusions of traditional wisdom and modern innovations are more effective means to achieve sustainability solutions. Thirdly, the emphasis on occupant comfort and social acceptance indicates technological advancements in building design also having to meet human-centric factors. It thereby fits the theoretical framework of sustainable development, which emphasizes the fine balance among the three dimensions in such initiatives: environment, economic, and social.

4.4. Response to the Hypothesis

The hypothesis of the article is that passive solar design elements can tremendously enhance thermal comfort in residential buildings. With this hypothesis, the authors respond in the light of making a detailed analysis of the mentioned passive solar strategies. It discusses how building orientation, shading devices, and incorporation of thermal mass interact to affect the indoor thermal environment. Orientation: The aspect of optimum orientation, which maximizes the winter solar gains while minimizing overheating during summer, is taken up for investigation. This likely includes simulations or empirical data comparing different orientations and their influences on indoor temperatures. Shading: The authors test various shading techniques, such as overhangs, louvres, and vegetation, to try to pinpoint their effectiveness at blocking excess solar radiation during hot periods. They investigate how shading devices can allow comfortable indoor temperatures without necessarily allowing natural light. Thermal Mass: The study explores the contribution of thermal mass toward the stabilization of indoor temperature conditions through the absorption and release of heat. Comparisons between various differently configured buildings, in terms of their thermal masses and their daily temperature fluctuations, are hence imperative.

5. Conclusions

A review of passive solar thermal comfort techniques used in both hot and cold climates is presented in this article, with bibliometric and bibliographic methods used to visualize the data. An examination of research-related publications. This study was conducted in response to growing worries about improving thermal comfort and reducing energy consumption in buildings. Because of this, there is a growing interest in determining how passive solar design strategies affect the thermal comfort of indoor spaces. By examining publications, nations, authors, and keywords, this review aimed to better understand current trends and future directions in this field's research. The number of publications in the subject area increased rapidly and significantly between 2015 and 2017, then began to fall considerably in 2020. Authors Yu and Givoni B. were the authors with the most cited references, while Wang, Zhaojun, Yang, Liu, Kurnitski, and Jarek. The Energy and Buildings journal had the highest number of articles and has shown considerable steady growth over the years, followed by Building and Environment. Most documents are in China, followed by those from Italy, England, Japan, the United States, and Canada. Significant research efforts are required in the field of passive solar strategies to yield substantial improvements in thermal comfort. This, in turn, can contribute to the reduction of climate emissions and the attainment of long-term energy efficiency goals. The main focus of the research is on simulation, with a particular focus on topics related to heating, cooling, and thermal comfort methods, but despite

extensive research in these areas, observations show that energy consumption remains unchanged. There is a lack of comprehensive research detailing passive solar building solutions that are critical to addressing future climate change challenges.

This study tackles key challenges associated with energy consumption in residential buildings by showcasing the effectiveness of passive solar strategies. It adds to the body of literature on sustainable architecture by providing fact-based information on how these strategies enhance thermal comfort and reduce energy use. The results confirm the research questions and hypotheses, underlining the importance of incorporating passive solar design principles in building practice. Thereafter, the study acknowledges limitations to this study, such as climatic conditions and building designs which vary. Further research is required to fully understand and increase the generality of these findings.

Data availability statement

The original contributions presented are readily available on request.

Ethics statements

No potentially identifiable human images or data is presented in this study.

Conflict of Interests

The author declares no conflict of interest.

References

- Ahmed, T., Kumar, P., & Mottet, L. (2021). The challenges of thermal comfort, heatwave resilience and indoor air quality. *Renewable and Sustainable Energy Reviews*, 138, 110669. <https://doi.org/10.1016/j.rser.2020.110669>
- Arif, M., Katafygiotou, M., Mazroei, A., Kaushik, A., & Elsarrag, E. (2016). Impact of indoor environmental quality on occupant well-being and comfort: A review of the literature. *International Journal of Sustainable Built Environment*, 5(1), 1-11. <https://doi.org/10.1016/j.ijsbe.2016.03.006>
- Athienitis, A., Cellura, M., Chen, Y., Delisle, V., Bourdoukan, P., & Kapsis, K. (2015). Modeling and design of Net ZEBs as integrated energy systems. In *Modeling, Design, and Optimization of Net-Zero Energy Buildings* (pp. 9-74). Wiley. <https://doi.org/10.1002/9781119137470.ch2>
- Bakirci, K., Ozyurt, O., Comakli, K., & Comakli, O. (2011). Energy analysis of a solar-ground source heat pump system with vertical closed-loop for heating applications. *Renewable Energy*, 36(5), 3224-3232. <https://doi.org/10.1016/j.renene.2011.01.028>
- Borgman, C. L., & Furner, J. (2002). Scholarly communication and bibliometrics. *Annual Review of Information Science and Technology*, 36(1), 1-53. <https://doi.org/10.1002/aris.1440360102>
- Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Sage. ISBN: 9780761909613
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Cao, X., Dai, X., & Liu, J. (2016). Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade. *Energy and Buildings*, 128, 198-213. <https://doi.org/10.1016/j.enbuild.2016.06.089>
- Chiras, D. D. (2002). *The solar house: Passive heating and cooling*. Chelsea Green Publishing. ISBN: 9781931498128
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285-296. <https://doi.org/10.1016/j.jbusres.2021.04.070>

- Emmi, G., Zarrella, A., De Carli, M., & Galgaro, A. (2015). An analysis of solar assisted ground source heat pumps in cold climates. *Energy Conversion and Management*, 106, 660-675. <https://doi.org/10.1016/j.enconman.2015.10.010>
- Esen, M. (2000). Thermal performance of a solar-aided latent heat store used for space heating by heat pump. *Solar Energy*, 69(1), 15-25. [https://doi.org/10.1016/S0038-092X\(00\)00022-1](https://doi.org/10.1016/S0038-092X(00)00022-1)
- Fang, Z., Li, N., Li, B., Luo, G., & Huang, Y. (2014). The effect of building envelope insulation on cooling energy consumption in summer. *Energy and Buildings*, 77, 197-205. <https://doi.org/10.1016/j.enbuild.2014.03.027>
- Ferrer-Rodríguez, J. P., Fernández, E. F., Fernández-Solas, Á., Almonacid, F., Talavera, D. L., & Pérez-Higueras, P. (2019). Optimization of an ultra-high CPV Cassegrain-Koehler unit with 2000× concentration ratio. *AIP Conference Proceedings*, 2149(1), 1-6. <https://doi.org/10.1063/1.5124132>
- Freewan, A. A. Y. (2014). Impact of external shading devices on thermal and daylighting performance of offices in hot climate regions. *Solar Energy*, 102, 14-30. <https://doi.org/10.1016/j.solener.2014.01.024>
- Givoni, B. (1992). Comfort, climate analysis and building design guidelines. *Energy and Buildings*, 18(1), 11-23. [https://doi.org/10.1016/0378-7788\(92\)90047-K](https://doi.org/10.1016/0378-7788(92)90047-K)
- Godin, B. (2006). On the origins of bibliometrics. *Scientometrics*, 68(1), 109-133. <https://doi.org/10.1007/s11192-006-0086-0>
- Gou, S., Nik, V. M., Scartezzini, J. L., Zhao, Q., & Li, Z. (2018). Passive design optimization of newly-built residential buildings in Shanghai for improving indoor thermal comfort while reducing building energy demand. *Energy and Buildings*, 169, 484-506. <https://doi.org/10.1016/j.enbuild.2018.03.062>
- Gross, G. (2021). A numerical study on the effects of natural ventilation on summer nighttime indoor temperatures in an urban area. *Meteorologische Zeitschrift*, 30(3), 227-236. <https://doi.org/10.1127/metz/2021/1069>
- Guarino, F., Athienitis, A., Cellura, M., & Bastien, D. (2017). PCM thermal storage design in buildings: Experimental studies and applications to solarium in cold climates. *Applied Energy*, 185, 95-106. <https://doi.org/10.1016/j.apenergy.2016.10.080>
- Guest, G., MacQueen, K. M., & Namey, E. E. (2011). *Applied thematic analysis*. SAGE Publications. ISBN: 978-1412971676
- He, C., Hou, Y., Ding, L., & Li, P. (2021). Visualized literature review on sustainable building renovation. *Journal of Building Engineering*, 44, 102622. <https://doi.org/10.1016/j.jobbe.2021.102622>
- Hobbi, A., & Siddiqui, K. (2009). Optimal design of a forced circulation solar water heating system for a residential unit in a cold climate using TRNSYS. *Solar Energy*, 83(5), 700-714. <https://doi.org/10.1016/j.solener.2008.10.018>
- Hou, C., Chen, C., Zhou, Y., Yang, Z., & Wei, S. (2021). Investigation of natural ventilation performance of large space circular coal storage dome. *Building Simulation*, 14, 1077-1093. <https://doi.org/10.1007/s12273-021-0761-3>
- Huang, C., Zou, Z., Li, M., Wang, X., Li, W., Huang, W., Yang, J., & Xiao, X. (2007). Measurements of indoor thermal environment and energy analysis in a large space building in typical seasons. *Building and Environment*, 42(5), 1869-1877. <https://doi.org/10.1016/j.buildenv.2006.02.021>
- Ismail, K. A. R., Salinas, C. T., & Henriquez, J. R. (2008). Comparison between PCM-filled glass windows and absorbing gas-filled windows. *Energy and Buildings*, 40(5), 710-719. <https://doi.org/10.1016/j.enbuild.2007.05.002>
- Jokisalo, J., Kurnitski, J., Korpi, M., Kalamees, T., & Vinha, J. (2009). Building leakage, infiltration, and energy performance analyses for Finnish detached houses. *Building and Environment*, 44(2), 377-387. <https://doi.org/10.1016/j.buildenv.2008.03.014>

- Kapsis, K., Dermardiros, V., & Athienitis, A. K. (2015). Daylight performance of perimeter office façades utilizing semi-transparent photovoltaic windows: A simulation study. *Energy Procedia*, 78, 334-339. <https://doi.org/10.1016/j.egypro.2015.11.639>
- Ketwong, W., Deethayat, T., & Kiatsiroat, T. (2021). Performance enhancement of air conditioner in a hot climate by condenser cooling with cool air generated by direct evaporative cooling. *Case Studies in Thermal Engineering*, 26, 101127.