UNIVERSIDAD DISTRITAL FRANCISCO JOSE DE CALDAS

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https://doi.org/10.14483/issn.2248-4728

VISIÓN ELECTRÓNICA

Maximizing winter comfort: A global bibliometric study of passive solar heating techniques

Maximizar el confort invernal: Un estudio bibliométrico global de las técnicas de calefacción solar pasiva

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Abstract

Passive heating techniques offer a sustainable alternative for harnessing solar energy to heat buildings during the winter months. This paper presents a bibliometric analysis of research on passive heating methods from 2004 to 2024. Using data from the Scopus database and VOSviewer software, the study examines the evolution of publications in this field, exploring the variety of passive heating techniques and their integration with solar radiation. Key research trends are identified through an analysis of term co-occurrence, leading authors, countries, continents, and institutions. The study highlights the most researched passive heating techniques and assesses their correlation with global solar radiation maps. Additionally, it

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evaluates the contributions from different continents, providing a comprehensive view of the global landscape of passive heating technologies and their potential impact on energy sustainability.

Keywords: *Bibliometric Analysis, Passive Heating, Solar Energy, Solar Radiation, Winter Comfort*

Resumen

Las técnicas de calefacción pasiva ofrecen una alternativa sostenible para aprovechar la energía solar para calentar los edificios durante los meses de invierno. Este Article presenta un análisis bibliométrico de la investigación sobre métodos pasivos de calefacción desde 2004 hasta 2024. Utilizando datos de la base de datos Scopus y el software VOSviewer, el estudio examina la evolución de las publicaciones en este campo, explorando la variedad de técnicas de calefacción pasiva y su integración con la radiación solar. Las principales tendencias de investigación se identifican mediante un análisis de la co-ocurrencia de términos, autores principales, países, continentes e instituciones. El estudio destaca las técnicas de calefacción pasiva más investigadas y evalúa su correlación con los mapas globales de radiación solar. Además, evalúa las contribuciones de los distintos continentes, proporcionando una visión completa del panorama mundial de las tecnologías de calefacción pasiva y su impacto potencial en la sostenibilidad energética.

Palabras clave: *Análisis bibliométrico, calefacción pasiva, energía solar, radiación solar, confort invernal*

1. Introduction

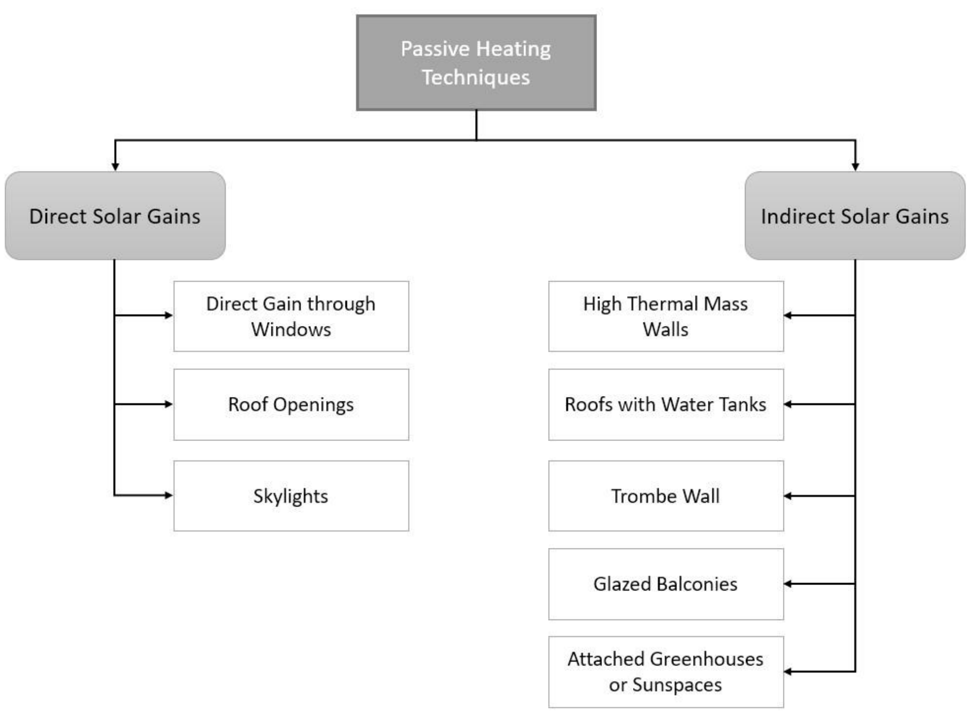
Sustainability in the building sector revolves around a holistic approach to constructing and maintaining building structures in such a way that their ecological footprint impact is the lowest *and resources are used appropriately [1]. This type of building concept has grown in recent decades, in particular because of the worldwide need to mitigate emissions to the atmosphere, without neglecting the social, economic and technical component [2]. Globally, the building sector contributed 39% of carbon dioxide (CO_2) emissions and accounted for 35% of total energy consumption by 2022 [3]. These figures underline the need to promote sustainable construction practices as a strategy to combat climate change.*

In addition, the International Energy Agency states that approximately 50% of the world's energy consumption is for heating, cooling and artificial lighting within the building sector [4]. Most of the energy consumption is directly attributed to heat transferred from the building envelope [5]. To combat this issue, passive and active energy efficiency measures have recently become popular around the world [6], specifically in North America and Europe [7].

Among the many strategies and technologies currently available to reduce energy needs in buildings, the concept of bioclimatic architecture with the application of passive heating techniques [8]. These techniques applied in buildings emerge as an effective strategy to reduce energy dependence on non-renewable sources, taking advantage of natural resources in a sustainable manner [9]. In temperate and cold climate regions, adequate solar exposure is essential for the energy performance of a building, since it allows capturing and retaining heat in a natural way. The design of buildings with correct orientation, use of materials with high thermal inertia and the incorporation of elements such as windows, skylights and Trombe walls, among others, are key to maximize direct and indirect solar Gains [10]. These techniques not only contribute to indoor thermal comfort, but also minimize energy losses, reducing heating consumption and greenhouse gas emissions [11].

The use of passive heating systems involves a thorough understanding of the principles of solar energy and its interaction with building materials [12]. The correct application of these techniques, such as the management of direct solar gains through south-facing windows and the use of high thermal inertia walls, makes it possible to maintain comfortable indoor temperatures with a minimum of mechanical intervention. In addition, the integration of passive heating systems with other energy efficiency measures, such as natural ventilation and the use of advanced glazing, can lead to near zero energy consumption (nZEB) and carbon neutral buildings [13].

Figure 1 shows how the techniques are divided into direct and indirect solar gains, detailing the different options within each category. Each technique plays a crucial role in the design of sustainable buildings, allowing to maximize the use of solar energy for passive heating. **Figure 1.** *Classification of Passive heating techniques*



Source: Own elaboration. Information taken from [14]

Direct solar gains are achieved by solar radiation entering through glazed surfaces, such as windows, roofs, and skylights, which heat interior surfaces and air [15]. Building orientation, size and type of glazing, and use of thermal materials are crucial to maximize efficiency. Southfacing windows and advanced glazing help control thermal gains and losses, optimizing indoor comfort [16]. Indirect solar gains are based on the accumulation and transfer of heat in adjacent elements, such as high thermal inertia walls, water tank roofs and Trombe walls [17]. These systems store heat during the day and release it slowly during the night, maintaining a stable indoor temperature [18]. Glazed balconies and conservatories act as thermal buffers, preheating the air before it enters the living spaces, which reduces heating demand and improves the energy efficiency of the Building [19].

Finally, this study presents a bibliometric analysis of research on passive heating techniques from 2004 to 2024, using data from the Scopus database and VOSviewer software. Although previous reviews on this topic exist, an analysis with this specific approach has not been performed. Throughout this paper, the evolution of publications in the field of passive heating is explored, identifying the main trends, authors, countries, continents and universities involved in the research. In addition, the correlation between the most investigated passive heating techniques and global solar radiation maps is evaluated. The structure of the study is divided into four sections: Section 1 introduces the general context; Section 2 details the review and analysis methodology; Section 3 presents the results and discussion; and Section 4 concludes with the implications and potential impact of passive solar heating technologies worldwide.y el impacto potencial de las tecnologías de calentamiento solar pasivo a nivel mundial.

2. Introduction

2.1. Study design and objective

This study has been designed as a bibliometric analysis with the objective of evaluating the evolution of research in passive heating techniques in buildings during the period 2004-2024. It aims to identify the main trends, key players, and the geographical and institutional distribution of research in this field, with a focus on the integration of passive techniques with energy efficiency.

2.2. Database selection

For the bibliometric analysis, the Scopus database was selected because of its broad coverage of scientific publications and its ability to provide detailed data for trend analysis. Although other databases such as Web of Science are recognized, Scopus was chosen because of its accessibility and functionality for this type of study.

2.3. Database selection

Specific keywords were defined to capture research on passive heating techniques. The search strategy included a combination of terms such as "Passive Heating," "Solar Gains," "Direct Solar Gains," and "Indirect Solar Gains," among others. The search was pe*rformed using Boolean operators to refine the results and ensure the relevance of the documents found.* **Table 1.** *Search equations*

Item	*Keywords*	*Equation*	*Number of documents*
1	*Passive Heating*	*Passive AND Heating*	*755*
2	*Passive Heating Techniques*	*Passive AND Heating AND Techniques*	*85*

3	*Passive Heating Direct*	*Passive AND Heating AND Direct*	*41*
4	*Passive Heating Indirect*	*Passive AND Heating AND Indirect*	*13*

2.4. Database selection

For data analysis, VOSviewer software was used to visualize co-occurrence networks of terms, authors and affiliations. This software facilitates the identification of trends, areas of focus and collaborations in passive heating techniques research. The analysis focused on:

- *Co-occurrence of key terms to identify research trends.*
- *Patterns of authorship and collaboration between institutions.*
- *Geographical distribution of research, including countries and continents.*
- *Identification of the journals with the highest impact in the field.*

2.5. Limitations

Only articles published in scientific journals between 2004 and 2024 were included. Documents in languages other than English were excluded to maintain consistency and comparability of the analysis. In addition, filters were applied to exclude gray literature and non-peer-reviewed publications. Additionally, the following limitations are presented:

- *Database: The exclusivity of Scopus may limit the inclusivity of the literature, although the variation in results is expected to be minimal.*

- *Language: The inclusion of articles only in English may leave out relevant research published in other languages.*
- *Keywords: The selection of keywords, although specific, may not capture all facets of the field, which could limit the scope of the analysis.*

3. Results and Discussion

A total of 755 documents were evaluated using the search string “Passive Heating,” as shown in Table 1. Subsequently, refining the search with Equation 2 “Passive Heating AND Techniques,” identified 85 documents that are directly related to passi*ve heating techniques. The trend of publications over time is presented in Figure 1, where two decades are observed: the first between 2004 and 2013, and the second between 2014 and 2024.*

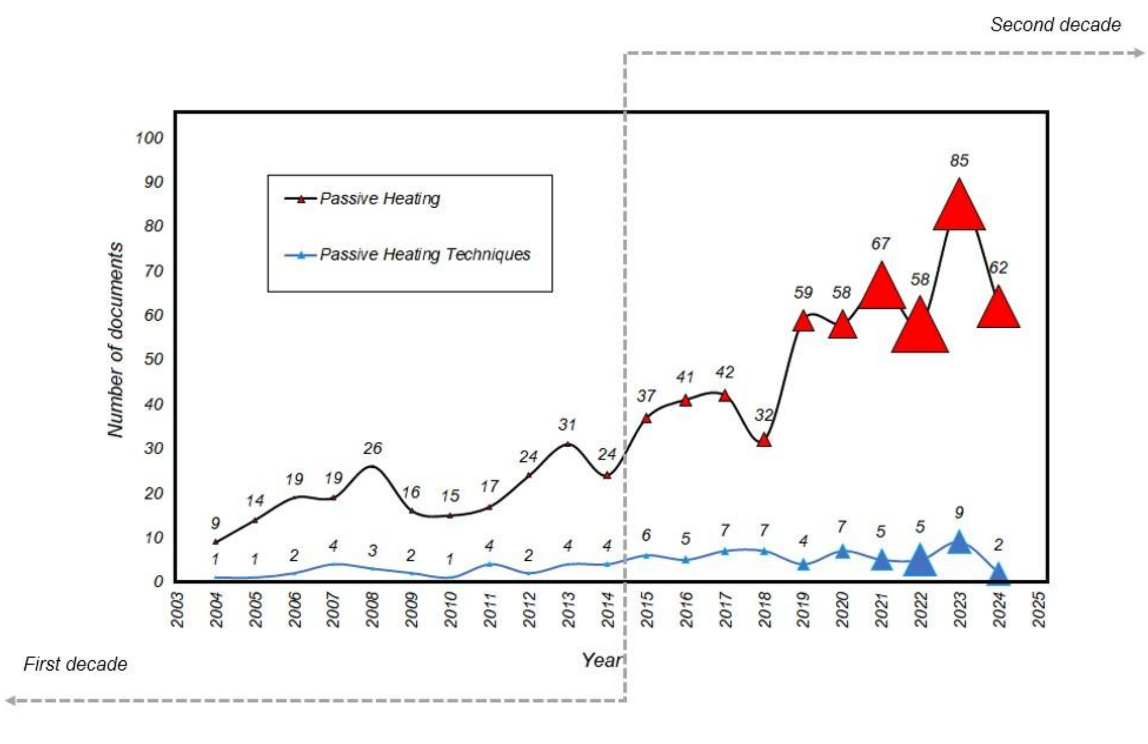
The trend in Figure 2 shows an increase in the number of papers between the first and second decade. Specifically, a significant increase is observed in publications related to the term “Passive Heating,” with an average increase of 2.7 times more papers in the second decade *(average of 51.36 papers per year) compared to the first (average of 19 papers per year). In contrast, publications on specific passive heating techniques also show growth, with an average increase of 2.31 times in the second decade, where the annual average increases from 2.4 to 5.54 documents.*

In the first decade, growth is more gradual, remaining in a range of between 1 and 31 publications per year for “Passive Heating.” On the other hand, publications on “Passive Heating Techniques” remain low, fluctuating between 1 and 4 papers per year. Although th*ere is growth in this decade, its behavior is much more linear and limited compared to the results obtained in the second decade.*

In contrast, the behavior in the second decade changes more noticeably. Starting in 2015, publications related to “Passive Heating” begin to increase considerably, reaching a maximum *of 85 papers in 2023. This growth follows an exponential curve compared to the first decade. Passive heating techniques, although in smaller numbers, also show a steady increase during this period, reaching their highest point in 2023, with 9 publications.*

The trend in recent years, between 2020 and 2024, reflects a consolidation in research related to passive warming, with high levels of scientific production, far exceeding the values of the first decade of the analysis. Although the growth between 2023 and 2024 shows a slight decrease in the number of publications related to passive heating techniques, the numbers are still considerably high, evidencing a sustained interest and continued relevance of the topic in the scientific community.

Figure 2. *Classification of Passive heating techniques*



An analysis of the distribution of published papers by continent, as shown in Figure 3, reveals that Europe leads with 45.28% of the total number of publications. This percentage reflects the active research on passive heating techniques in European institutions. Asia follows with 29.24%, indicating a considerable contribution to this field, driven by countries such as India *and China. North America ranks third, with 13.21% of the papers, mainly from the United States and Canada.*

Africa and Oceania have smaller shares, with 5.66% and 3.77%, respectively. These regions are still emerging in terms of research production in this field, but show a growing interest in passive heating techniques, especially in countries with extreme climates. South America has the lowest percentage with 2.83%, indicating a more limited participation in this field of study. This geographical distribution of research reflects how regions such as Europe and Asia, with strong research infrastructures, dominate the publication on passive heating techniques. The lower contributions from Africa, Oceania and South America suggest that these regions could benefit from further exploration and investment in energy efficient technologies.

Figure 3. *Participation in the publication of articles in Scopus for the period 2004-2024 with total contribution (%)*

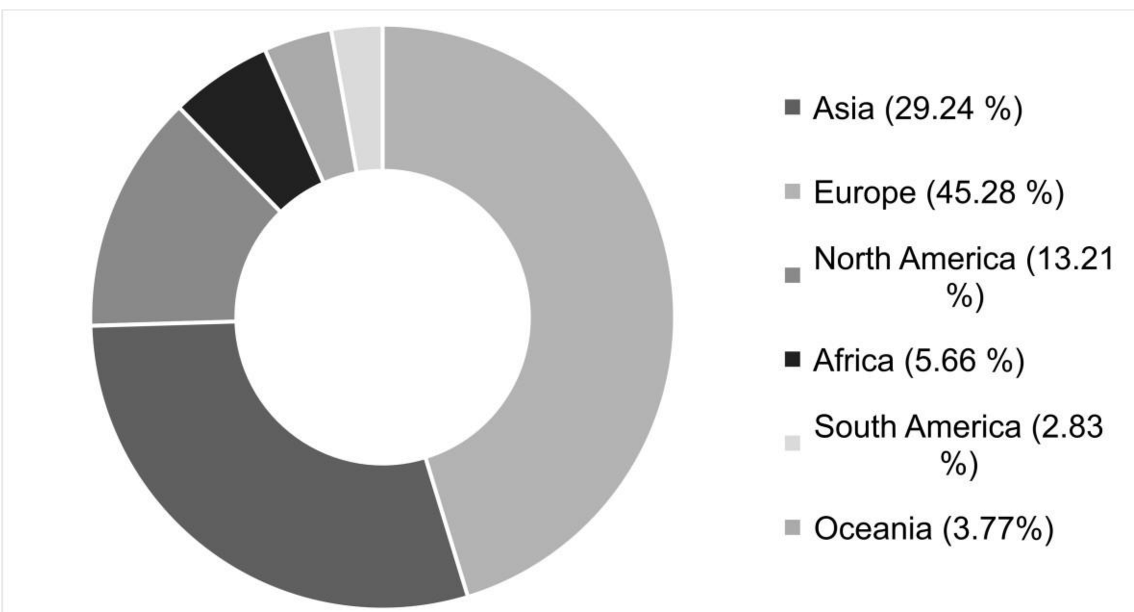
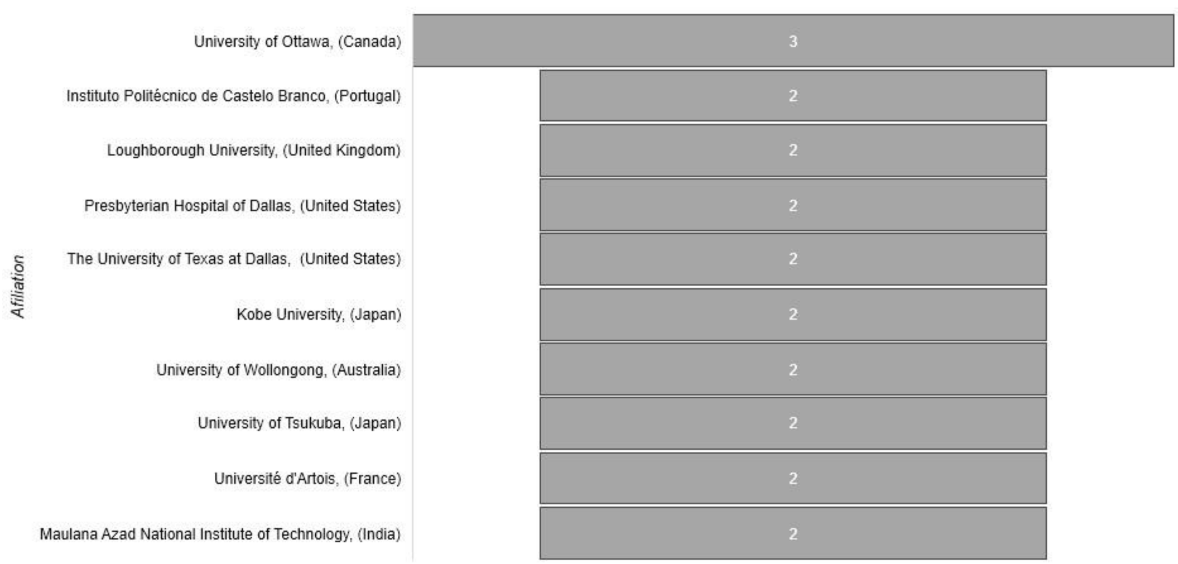


Figure 4 shows the top 10 institutions that have contributed publications on passive warming and its techniques between 2004 and 2024. The University of Ottawa (Canada) stands out, with 3 publications, leading the contributions in this field of research. In Europe, institutions such as the Polytechnic Institute of Castelo Branco (Portugal) and Loughborough University (United

Kingdom) have contributed 2 publications each, reflecting a growing interest in this topic. Université d'Artois (France) is also included with a similar participation.

In Asia, universities such as Kobe University and the University of Tsukuba in Japan, together with the Maulana Azad National Institute of Technology (India), have made important contributions, each with 2 published papers. This reflects an active participation of Asian institutions in research on passive heating techniques. The presence of these universities indicates a growing interest in this technology in regions with diverse climates, underscoring the importance of energy efficiency in diverse geographies.

Figure 4. *Affiliations*

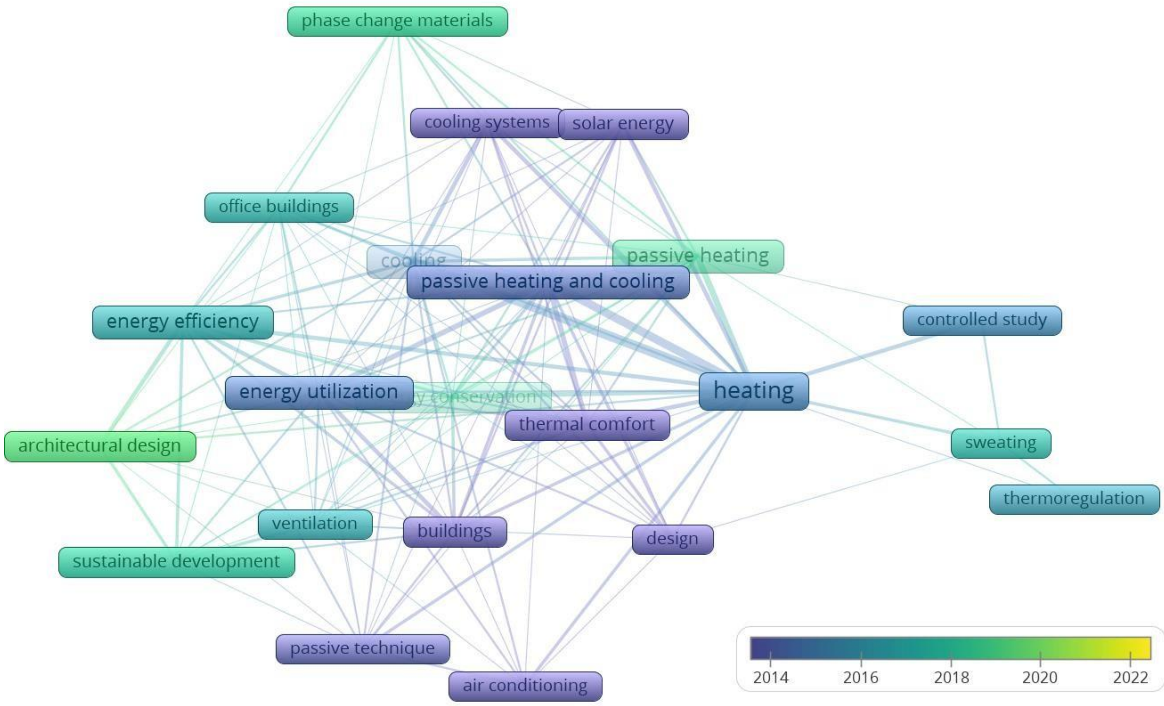


In Oceania and North America, institutions such as the University of Wollongong (Australia) and the Presbyterian Hospital of Dallas together with The University of Texas at Dallas in the United States, have also contributed 2 publications each. This panorama of collaborations reflects a global effort in the development of research on passive warming, with significant contributions *from institutions in various parts of the world, led mainly by universities in North America, Europe and Asia.*

Based on the co-occurrence analysis of terms presented in Figure 5, the evolution of passive heating research and techniques in the period 2014-2024 is evident. Several key terms stand out, such as “passive heating,” “energy efficiency” and “thermal insulation,” which show a steady growth in interest over time. In particular, “passive heating” and “energy efficiency” are *represented in shades of blue and green, indicating that they have been recurring themes since the beginning of the period, with a strong interrelationship between them and other complementary technologies.*

The term “thermal insulation” has also gained popularity, highlighted in lighter shades around *2022, suggesting a more recent focus on research into these techniques. On the other hand,* concepts such as “energy savings” and “sustainable buildings” appear in shades of green and *yellow, reflecting an emerging interest in recent years, especially in the 2020-2022 timeframe. These terms underline the growing attention towards improving the energy efficiency and sustainability of passive heating systems.*

Figure 5. *Co-occurrence of terms*



Finally, terms such as "solar gains" and "green building" in warmer tones (yellow) have gained *prominence in recent years, indicating that the most recent research (2023-2024) is focused on integrating passive heating technologies with sustainable solutions in the building sector. The analysis reveals how research has evolved from more general topics to more specific approaches to energy efficiency and sustainability in the last few years of the period analyzed.*

In a meticulous study covering 85 documents filtered in Search Equation 3 and 4, an analysis was carried out to distinguish between direct and indirect passive solar heating techniques. Of the 13 documents that focused on indirect passive heating techniques, 4 of them were identified as not relevant to the development of the present review. Therefore, the table below only includes 9 of these studies, focusing on those that contribute significantly to the field of indirect passive heating.

Table 2 shows that the most common types of indirect solar gains include Trombe walls and water tank roofs, cited in several important papers by authors such as Mo, Zhang, Yao, Li, *DeBacker, and Krzaczek, among others. These elements are frequently used to evaluate energy savings potential and thermal performance in different climates. For example, Fernandes and Krüger (2021) specifically evaluated the thermal performance of a rooftop pond system under subtropical conditions, highlighting the usefulness of this technique in specific climates.*

Other indirect solar gain techniques, such as high thermal mass walls and glazed balconies, are also mentioned in several studies, reflecting a diversity of approaches and practical applications in passive heating research. These studies address not only thermal comfort but also thermal performance stability and energy efficiency improvement in existing buildings, as seen in the work of Calderaro and Agnoli (2021). This table reflects a growing and diversified interest in optimizing passive heating strategies, demonstrating the adaptability and relevance of these techniques in the context of sustainability and energy efficiency in modern architecture.

Table 2. *Ranking papers focusing their research on passive heating techniques Indirect for the period 2004-2024.*

Source	Purpose	Type of Research	Type of Document	Indirect Solar Gains
[20]	*Evaluate the energy saving potential of passive solar heating systems in different climates.*	*Quantitative*	*Article*	*Trombe wall, roofs with water tanks*
[21]	*Evaluate hybrid active/passive heating systems for thermal microclimate control.*	*Experimental*	*Conference minutes*	*High thermal mass walls*
[22]	*Application of gain scheduling control in passive heating and cooling systems.*	*Experimental*	*Article*	*Trombe wall, roofs with water tanks*
[23]	*Evaluating the thermal performance of a rooftop pond system under subtropical conditions.*	*Experimental*	*Conference minutes*	*Roofs with water tanks*
[24]	*Provide thermal comfort inside solar houses using various heating technology concepts.*	*Theoretical*	*Capítulo Libro de*	*Glazed balconies, attached greenhouses, sunspaces*
[25].	*Aplicar técnicas pasivas de refrigeración y calefacción para lograr el confort térmico en climas cálidos.*	*Experimental*	*Article*	*Trombe wall, glazed balconies, sunspaces*

[26]	*Investigate thermal performance and stability of the Thermal Barrier in indirect heating and cooling of residential buildings*	*Experimental*	*Article*	*High thermal mass walls, roofs with water tanks*
[27].	*Rescue energy performance of a building employed as a library and improve comfort with passive heating/cooling strategies*	*Simulation*	*Article*	*Trombe wall, glazed balconies, attached greenhouses*
[28].	*Compare prolactin and blood pressure responses to active and passive heating*	*Experimental*	*Article*	*Indirect heating not clearly stated*

Of the 41 papers on direct passive heating techniques, 25 key studies were selected that contribute significantly to the development and understanding of these strategies. These papers focus on different applications of direct solar gains, highlighting the most common ones such as the use of sunlight through windows, skylights and roof openings. These techniques allow the entry of direct solar radiation, optimizing thermal gain in interior spaces.

The table presented evidences that the use of windows is the most frequently used technique to take advantage of direct solar gains, present in multiple studies by authors such as Mo, W., Zhang, G. (2023), Chávez, J.R.G., and Melchor, F.F. (2023). In addition, skylights also play a relevant role in experimental investigations, as observed in the work of Ben-Alon, L. and Rempel, A.R. (2023). The combination of windows and skylights appears as a common solution in cold and cloudy climates, which reflects the adaptability of these strategies to maximize thermal efficiency in buildings.

Another relevant method is the use of roof openings, applied in studies such as Kaplan, S. and Demirbek, D.M. (2023). This approach, along with skylights, is critical in heating strategies in areas where access to direct sunlight may be limited by architecture or climate. Taken together, these studies underscore the importance of direct passive heating techniques for improving energy efficiency and thermal comfort in a variety of climatic and geographic contexts.

Table 3. *Ranking papers focusing their research on passive heating techniques direct for the period 2020-2024.*

Source	Purpose	Type of Research	Type of Document	Tipo de direct solar Gains
[20]	*Evaluate the energy savings potential of passive solar heating systems in varied climates and develop a passive solar heating indicator (PSHI).*	*Quantitative*	*Article*	*Through windows*
[29]	*Controlling radiant energy for personal thermal management through passive radiative nanocomposite films.*	*Experimental*	*Article*	*Through roof openings*
[30]	*Evaluate a model predictive control (MPC) strategy for solar thermal heating systems integrated with thermal energy storage..*	*Experimental*	*Article*	*Through skylights*
[31]	*Propose a novel solar chimney design with absorber elements distributed in the air channel to improve thermal efficiency.*	*Experimental*	*Article*	*Through windows*
[32]	*Investigate the capabilities of raw earth and conventional buildings to provide passive thermal comfort in different climates.*	*Experimental*	*Article*	*Through skylights*
[33]	*Passive heating strategies in cold and cloudy climates to approach zero-energy buildings.*	*Experimental*	*Article*	*Through windows and skylights*
[34]	*Controlling passive heating and cooling in buildings using reinforcement learning algorithms.*	*Experimental*	*Article*	*Through windows*
[35]	*Evaluate the use of cold alleys as a passive source of energy in rural houses.*	*Experimental*	*Article*	*Through skylights*
[36]	*Analyze a passive heating system using a kitchen wall in rural homes.*	*Experimental*	*Article*	*Through roof openings*
[37]	*Define geo-climatic indicators for the potential of low-energy technologies in climate change.*	*Revisión*	*Book chapter*	*Through windows*
[38]	*Review the health benefits of passive warming and aerobic exercise.*	*Revisión*	*Article*	*Through skylights*
[39]	*Evaluate the use of Trombe walls in desert climates for passive heating and cooling.*	*Experimental*	*Article*	*Through windows*
[40].	*To evaluate the increase in temperature on the skin surface during transcranial direct current stimulation.*	*Experimental*	*Article*	*Through windows*
[41]	*Developing spatial zoning maps for passive heating and comfort strategies in India.*	*Quantitative*	*Article*	*Through windows*
[42]	*Describe a technique for calculating the start and end times of direct sunlight and accumulated solar radiation in passive heating systems.*	*Experimental*	*Article*	*Through skylights*

[43]	Develop a bioclimatic analysis tool to study the potential of passive heating and cooling strategies in India.	Quantitative	Article	Through windows
[44]	To investigate the effects of passive warming on systolic blood pressure and heart rate variability in conscious rats.	Experimental	Article	Through skylights
[45]	Review the concepts of passive heating and cooling in buildings and their impact on their thermal management.	Revisión	Article	Through windows and roof openings
[46]	Apply combined passive cooling and heating techniques to achieve thermal comfort in hot and dry climates.	Experimental	Article	Through windows
[47]	Develop a climate analysis tool for passive heating and cooling strategies in humid climates.	Quantitative	Article	Through skylights
[48]	To examine sex differences in postsynaptic sweating and cutaneous vasodilation.	Experimental	Article	Through roof openings
[49]	Deriving sustainable design guidelines from the vernacular architecture of Sana'a.	Theoretical	Book chapter	Through windows and skylights
[50]	Investigate energy conservation in buildings through the use of a Trombe wall.	Experimental	Article	Through windows
[51]	Develop a methane oxidation cover system to reduce greenhouse gas emissions from landfills in cold and semi-arid regions.	Experimental	Article	Through roof openings
[52]	Presenting the schematic design of a fine arts pavilion at the University of Nevada, utilizing passive and active solar technologies for the southwestern U.S.	Experimental	Article	Through windows, roof openings

4. Conclusions

Energy efficiency in buildings is crucial for reducing CO_2 emissions, given that the building sector accounts for a significant share of global energy consumption. Passive heating techniques, integrated into bioclimatic architecture, offer an effective solution to reduce energy demand. These strategies not only take advantage of natural resources, but also contribute to the thermal comfort of occupants and ultimately promote sustainability in building design and maintenance.

The use of direct and indirect solar gains stands out as an essential component of efficient building design. Direct solar gains, through windows and skylights, are key to capturing solar energy in temperate and cold climates. At the same time, indirect gains, such as Trombe walls and water tank roofs, allow heat to be stored and released, significantly reducing heating consumption. These techniques, in combination, have proven to be instrumental in minimizing the use of non-renewable energy and improving building efficiency.

The bibliometric analysis reflects a considerable increase in research on passive heating techniques, particularly in Europe and Asia, where most of the publications are concentrated. However, the lower participation of regions such as Africa, South America and Oceania indicates the need to strengthen research and implementation of these techniques in these areas. The development of solutions adapted to specific climatic contexts could have a significant impact on global sustainability.

Finally, the integration of passive heating techniques with other energy efficiency measures, such as natural ventilation and materials with high thermal inertia, is key to moving towards nearly zero-energy buildings (nZEB). These strategies not only contribute to reducing emissions, but also improve livability and comfort in buildings, offering a holistic solution that responds to both environmental challenges and human needs.

Acknowledgments

The authors thank the Technological Units of Santander - UTS, Industrial University of Santander - UIS and the Ministry of Science, Technology and Innovation MINCIENCIAS for funding this research through the project "Development of a computational methodological tool and renewable energy technologies for the energy transition in high mountain areas in postpandemic conditions" CD 82605 CT ICETEX 2022-0644, for their contribution and commitment to this research.

References

[1] R. Isaksson y M. Rosvall, «Understanding building sustainability – the case of Sweden», *Total Quality Management & Business Excellence*, vol. 0, n.º 0, pp. 1-15, doi: 10.1080/14783363.2020.1853520.

[2] D. Urge-Vorsatz *et al.*, «Advances toward a net-zero global building sector», *Annual Review of Environment and Resources*, vol. 45, pp. 227-269, 2023, doi: 10.1146/annurev-environ-012420-045843.

[3] S. Uniyal *et al.*, «Passive solar heated buildings for enhancing sustainability in the Indian Himalayas», *Renewable and Sustainable Energy Reviews*, vol. 200, p. 114586, ago. 2024, doi: 10.1016/j.rser.2024.114586.

[4] L. Hernández-Callejo, S. Gallardo-Saavedra, y V. Alonso-Gómez, «A review of photovoltaic systems: Design, operation and maintenance», *Solar Energy*, vol. 188, pp. 426-440, ago. 2019, doi: 10.1016/j.solener.2019.06.017.

[5] L. Zhou, F. Qi, y X. Yan, «A review of research on the passive effect of building photovoltaic systems and analysis of influencing factors», *Solar Energy*, vol. 278, p. 112766, ago. 2024, doi: 10.1016/j.solener.2024.112766.

[6] D. Amaripadath y D. J. Sailor, «Reassessing energy-efficient passive retrofits in terms of indoor environmental quality in residential buildings in the United States», *Energy and Buildings*, vol. 319, p. 114564, sep. 2024, doi: 10.1016/j.enbuild.2024.114564.

[7] V. Anand, V. L. Kadiri, y C. Putcha, «Passive buildings: a state-of-the-art review», *Journal of Infrastructure Preservation and Resilience*, vol. 4, n.º 1, p. 3, ene. 2023, doi: 10.1186/s43065-022-00068-z.

[8] K. Hilliaho, *Energy Saving Potential and Interior Temperatures of Glazed Spaces: Evaluation through Measurements and Simulations*. Tampere University of Technology, 2017. Accedido: 19 de septiembre de 2024. [En línea]. Disponible en: https://trepo.tuni.fi/handle/10024/114510

[9] A. F. Tzikopoulos, M. C. Karatza, y J. A. Paravantis, «Modeling energy efficiency of bioclimatic buildings», *Energy and Buildings*, vol. 37, n.º 5, pp. 529-544, may 2005, doi: 10.1016/j.enbuild.2004.09.002.

[10] J. Fernandes, R. Malheiro, M. de F. Castro, H. Gervásio, S. M. Silva, y R. Mateus, «Thermal Performance and Comfort Condition Analysis in a Vernacular Building with a Glazed Balcony», *Energies*, vol. 13, n.º 3, Art. n.º 3, ene. 2020, doi: 10.3390/en13030624.

[11] K. Hilliaho, A. Köliö, T. Pakkala, J. Lahdensivu, y J. Vinha, «Effects of added glazing on Balcony indoor temperatures: Field measurements», *Energy and Buildings*, vol. 128, pp. 458-472, sep. 2016, doi: 10.1016/j.enbuild.2016.07.025.

[12] O. B. Joergensen y O. J. Hendriksen, «Glazed balconies and sun spaces - Energy savers or energy wasters?», jul. 2002, Accedido: 19 de septiembre de 2024. [En línea]. Disponible en: https://www.osti.gov/etdeweb/biblio/20314815

[13] K. M. Bataineh y N. Fayez, «Analysis of thermal performance of building attached sunspace», *Energy and Buildings*, vol. 43, n.º 8, pp. 1863-1868, ago. 2011, doi: 10.1016/j.enbuild.2011.03.030.

[14] J. L. Toroxel y S. M. Silva, «A Review of Passive Solar Heating and Cooling Technologies Based on Bioclimatic and Vernacular Architecture», *Energies*, vol. 17, n.º 5, Art. n.º 5, ene. 2024, doi: 10.3390/en17051006.

[15] Y. Liu, J. Jiang, D. Wang, y J. Liu, «The passive solar heating technologies in rural school buildings in cold climates in China», *Journal of Building Physics*, vol. 41, n.º 4, pp. 339-359, ene. 2018, doi: 10.1177/1744259117707277.

[16] L. Pajek y M. Košir, «Exploring Climate-Change Impacts on Energy Efficiency and Overheating Vulnerability of Bioclimatic Residential Buildings under Central European Climate», *Sustainability*, vol. 13, n.º 12, Art. n.º 12, ene. 2021, doi: 10.3390/su13126791.

[17] M. J. N. Oliveira Panão, S. M. L. Camelo, y H. J. P. Gonçalves, «Solar Load Ratio and ISO 13790 methodologies: Indirect gains from sunspaces», *Energy and Buildings*, vol. 51, pp. 212-222, ago. 2012, doi: 10.1016/j.enbuild.2012.05.019.

[18] G. Gorgolis y D. Karamanis, «Solar energy materials for glazing technologies», *Solar Energy Materials and Solar Cells*, vol. 144, pp. 559-578, ene. 2016, doi: 10.1016/j.solmat.2015.09.040.

[19] R. V. Ralegaonkar y R. Gupta, «Review of intelligent building construction: A passive solar architecture approach», *Renewable and Sustainable Energy Reviews*, vol. 14, n.º 8, pp. 2238-2242, oct. 2010, doi: 10.1016/j.rser.2010.04.016.

[20] W. Mo, G. Zhang, X. Yao, Q. Li, y B. J. DeBacker, «Assessment of Passive Solar Heating Systems' Energy-Saving Potential across Varied Climatic Conditions: The Development of the Passive Solar Heating Indicator (PSHI)», *Buildings*, vol. 14, n.º 5, Art. n.º 5, may 2024, doi: 10.3390/buildings14051364.

[21] E. Beaudette, E. Foo, H. Woelfle, M. T. I. Molla, y L. Dunne, «Characterizing Hybrid Active/Passive Heating Systems for Thermal Microclimate Control», doi: 10.1115/DMD2021-1065.

[22] M. Krzaczek y Z. Kowalczuk, «Gain Scheduling Control applied to Thermal Barrier in systems of indirect passive heating and cooling of buildings», *Control Engineering Practice*, vol. 20, n.º 12, pp. 1325-1336, dic. 2021, doi: 10.1016/j.conengprac.2012.07.007.

[23] E. Krüger, L. Fernandes, y S. Lange, «Thermal performance of different configurations of a roof pond-based system for subtropical conditions», *Building and Environment*, vol. 107, pp. 90-98, oct. 2016, doi: 10.1016/j.buildenv.2016.07.021.

[24] G. Tiwari, A. Tiwari, y Shyam, «Solar House», 2020, pp. 417-470. doi: 10.1007/978-981-10-0807-8_10.

[25] J. R. G. Chávez y F. F. Melchor, «Application of Combined Passive Cooling and Passive Heating Techniques to Achieve Thermal Comfort in a Hot Dry Climate», *Energy Procedia*, vol. 57, pp. 1669-1676, ene. 2020, doi: 10.1016/j.egypro.2014.10.157.

[26] M. Krzaczek y Z. Kowalczuk, «Thermal Barrier as a technique of indirect heating and cooling for residential buildings», *Energy and Buildings*, vol. 43, n.º 4, pp. 823-837, abr. 2021, doi: 10.1016/j.enbuild.2010.12.002.

[27] V. Calderaro y S. Agnoli, «Passive heating and cooling strategies in an approaches of retrofit in Rome», *Energy and Buildings - ENERG BLDG*, vol. 39, pp. 875-885, ago. 2021, doi: 10.1016/j.enbuild.2006.10.008.

[28] D. Low, A. Purvis, T. Reilly, y N. T. Cable, «The prolactin responses to active and passive heating in man», *Experimental Physiology*, vol. 90, n.º 6, pp. 909-917, 2021, doi: 10.1113/expphysiol.2005.031294.

[29] S. Kaplan, D. M. Demirbek, y N. Korkmaz Memis, «Design of passive radiative heating nanocomposite films by managing natural radiation energy», *International Journal of Clothing Science and Technology*, vol. ahead-of-print, n.º ahead-of-print, ene. 2024, doi: 10.1108/IJCST-01-2024-0019.

[30] Z. Wei y J. Calautit, «Evaluation of model predictive control (MPC) of solar thermal heating system with thermal energy storage for buildings with highly variable occupancy levels», *Build. Simul.*, vol. 16, n.º 10, pp. 1915-1931, oct. 2023, doi: 10.1007/s12273-023-1067-4.

[31] M. Corcione, L. Fontana, y A. Quintino, «First analysis of a novel design of a solar chimney with absorber elements distributed in the air channel», *Applied Thermal Engineering*, vol. 230, p. 120539, jul. 2023, doi: 10.1016/j.applthermaleng.2023.120539.

[32] L. Ben-Alon y A. R. Rempel, «Thermal comfort and passive survivability in earthen buildings», *Building and Environment*, vol. 238, p. 110339, jun. 2023, doi: 10.1016/j.buildenv.2023.110339.

[33] K. Tungnung, A. Varma, Y. Kodama, K. Takemasa, G. Pde, y S. Roy, «Parametric strategies on passive heating techniques in cold-cloudy climate, Shillong towards net-zero energy», *AIP Conference Proceedings*, vol. 2760, n.º 1, p. 020022, jun. 2023, doi: 10.1063/5.0149181.

[34] B. Park, A. R. Rempel, A. K. L. Lai, J. Chiaramonte, y S. Mishra, «Reinforcement Learning for Control of Passive Heating and Cooling in Buildings∗», *IFAC-PapersOnLine*, vol. 54, n.º 20, pp. 907-912, ene. 2021, doi: 10.1016/j.ifacol.2021.11.287.

[35] X. Yao, S. Han, y B. J. Dewancker, «Study on the Combined Effect of Multiple Passive Energy-Saving Methods for Rural Houses with Cold Alleys», *Applied Sciences*, vol. 11, n.º 12, Art. n.º 12, ene. 2021, doi: 10.3390/app11125636.

[36] S. Yang, B. J. Dewancker, y S. Chen, «Study on the Passive Heating System of a Heated Cooking Wall in Dwellings: A Case Study of Traditional Dwellings in Southern Shaanxi, China», *Int J Environ Res Public Health*, vol. 18, n.º 7, p. 3745, abr. 2021, doi: 10.3390/ijerph18073745.

[37] G. Chiesa, «Geo-Climatic Indicators to Define Local Potential of Low-Energy Technologies Including Climate Changes», en *Bioclimatic Approaches in Urban and Building Design*, G. Chiesa, Ed., Cham: Springer International Publishing, 2021, pp. 383-400. doi: 10.1007/978-3-030-59328-5_20.

[38] T. Cullen *et al.*, «The health benefits of passive heating and aerobic exercise: To what extent do the mechanisms overlap?», *J Appl Physiol (1985)*, vol. 129, n.º 6, pp. 1304-1309, dic. 2020, doi: 10.1152/japplphysiol.00608.2020.

[39] M. Dabaieh, D. Maguid, D. El Mahdy, y O. Wanas, «An urban living lab monitoring and post occupancy evaluation for a Trombe wall proof of concept», *Solar Energy*, vol. 193, pp. 556-567, nov. 2019, doi: 10.1016/j.solener.2019.09.088.

[40] N. Khadka, A. L. Zannou, F. Zunara, D. Q. Truong, J. Dmochowski, y M. Bikson, «Minimal Heating at the Skin Surface During Transcranial Direct Current Stimulation», *Neuromodulation: Technology at the Neural Interface*, vol. 21, n.º 4, pp. 334-339, jun. 2018, doi: 10.1111/ner.12554.

[41] K. Naveen Kishore y J. Rekha, «A bioclimatic approach to develop spatial zoning maps for comfort, passive heating and cooling strategies within a composite zone of India», *Building and Environment*, vol. 128, pp. 190-215, ene. 2018, doi: 10.1016/j.buildenv.2017.11.029.

[42] N. R. Avezova y E. Yu. Rakhimov, «Orientation of heated premise in the design of insolation passive heating systems», *Appl. Sol. Energy*, vol. 53, n.º 4, pp. 338-343, oct. 2017, doi: 10.3103/S0003701X17040053.

[43] N. K. Khambadkone y R. Jain, «A bioclimatic analysis tool for investigation of the potential of passive cooling and heating strategies in a composite Indian climate», *Building and Environment*, vol. 123, pp. 469-493, oct. 2017, doi: 10.1016/j.buildenv.2017.07.023.

[44] A. G. Moura *et al.*, «Power spectrum analysis of cardiovascular variability during passive heating in conscious rats», *Journal of Thermal Biology*, vol. 62, pp. 20-29, dic. 2016, doi: 10.1016/j.jtherbio.2016.08.011.

[45] N. Gupta y G. N. Tiwari, «Review of passive heating/cooling systems of buildings», *Energy Science & Engineering*, vol. 4, n.º 5, pp. 305-333, 2016, doi: 10.1002/ese3.129.

[46] J. R. Chavez y F. Melchor, «Application of Combined Passive Cooling and Passive Heating Techniques to Achieve Thermal Comfort in a Hot Dry Climate», *Energy Procedia*, vol. 57, dic. 2014, doi: 10.1016/j.egypro.2014.10.157.

[47] A.-T. Nguyen y S. Reiter, «A climate analysis tool for passive heating and cooling strategies in hot humid climate based on Typical Meteorological Year data sets», *Energy and Buildings*, vol. 68, pp. 756-763, ene. 2014, doi: 10.1016/j.enbuild.2012.08.050.

[48] D. Gagnon, C. G. Crandall, y G. P. Kenny, «Sex differences in postsynaptic sweating and cutaneous vasodilation», *J Appl Physiol (1985)*, vol. 114, n.º 3, pp. 394-401, feb. 2013, doi: 10.1152/japplphysiol.00877.2012.

[49] K. Al-Sallal, «Vernacular Tower Architecture of Sana'a: Theory and Method for Deriving Sustainable Design Guidelines», 2014.

[50] A. Chel, J. K. Nayak, y G. Kaushik, «Energy conservation in honey storage building using Trombe wall», *Energy and Buildings*, vol. 40, n.º 9, pp. 1643-1650, ene. 2008, doi: 10.1016/j.enbuild.2008.02.019.

[51] C. A. Zeiss, «Accelerated methane oxidation cover system to reduce greenhouse gas emissions from MSW landfills in cold, semi-arid regions», *Water Air Soil Pollut*, vol. 176, n.º 1, pp. 285-306, oct. 2006, doi: 10.1007/s11270-006-9169z.

[52] A. Fernández-González y D. Overbey, «Proposed Fine Arts Pavilion at the University of Nevada, Las Vegas: The Beauty of Green Design», *Solar World Congress: Solar Energy: Bringing Water to the World*, ago. 2005, [En línea]. Disponible en: https://digitalscholarship.unlv.edu/arch_fac_articles/10