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REVIEW

Sunlight as a Fundamental Resource in Bioclimatic and Sustainable Architectural Design

La Luz Solar como Recurso Fundamental en el Diseño Arquitectónico Bioclimático y Sostenible

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ABSTRACT

Objective: to describe how bioclimatic architecture and sustainable design intelligently integrate sunlight to promote more energy-efficient buildings and create living spaces that promote human well-being and harmony with the natural environment.
Method: a comprehensive narrative review was conducted by consulting databases such as Archidaily, Google Scholar, Scielo and Journal of Architectural Lighting, using key terms related to the sun and bioclimatic architecture, in publications from 2019 to 2024, and selecting 23 relevant articles after a rigorous filtering process.
Results: the historical and contemporary importance of the sun in architectural design is evidenced, evidencing how diverse cultures have implemented strategies to harness sunlight and photovoltaics. Examples of integration of solar technologies, passive techniques for thermal control, and the inspiring influence of the sun on visionary architects such as Le Corbusier were highlighted.
Conclusion: the sun is not only a practical source for solving energy and environmental challenges, but also an opportunity to design healthier, more sustainable and aesthetically enriching environments. The need for further research on new methodologies and strategies to enhance the efficient use of solar energy in future architecture is pointed out.

Keywords: Architecture; Architectural Design; The Sun; Agent Activ.

RESUMEN

Objetivo: describir cómo la arquitectura bioclimática y el diseño sostenible integran de manera inteligente la luz solar para promover construcciones más eficientes energéticamente y crear espacios habitables que fomenten el bienestar humano y la armonía con el entorno natural.
Método: se realizó una revisión narrativa exhaustiva consultando bases de datos como Archidaily, Google Académico, Scielo y Journal of Architectural Lighting, utilizando términos clave relacionados con el sol y la arquitectura bioclimática, en publicaciones de 2019 a 2024, y seleccionando 23 artículos relevantes tras un riguroso proceso de filtrado.
Resultados: se evidencia la importancia histórica y contemporánea del sol en el diseño arquitectónico, evidenciando cómo diversas culturas han implementado estrategias para aprovechar la luz solar y la energía fotovoltaica. Se destacaron ejemplos de integración de tecnologías solares, técnicas pasivas para el control térmico, y la influencia inspiradora del sol en arquitectos visionarios como Le Corbusier.

Conclusión: el sol no solo es una fuente práctica para resolver desafíos energéticos y ambientales, sino también una oportunidad para diseñar entornos más saludables, sostenibles y estéticamente enriquecedores. Se señala la necesidad de continuar investigando sobre nuevas metodologías y estrategias para potenciar el uso eficiente de la energía solar en la arquitectura futura.

Palabras clave: Arquitectura; Diseño Arquitectónico; El Sol; Agente Activo; Diseño Pasivo; Edificaciones.

INTRODUCTION

Throughout history, the sun has been an essential element that has captured human interest as a primary source of light and thermal energy and as a determining factor in the configuration of built spaces. Beyond its energetic function, its influence has been the subject of in-depth study and practical application in architecture, especially in the bioclimatic field. In this context, the sun is positioned as a key component that conditions both the design and the environmental behavior of buildings, modulating parameters such as natural lighting, thermal gain, and ventilation.[1]

According to Rosso, solar radiation's diurnal and seasonal variability becomes a fundamental resource in bioclimatic design, as it directly impacts users' spatial perception and thermal comfort. Correct orientation and the appropriate selection of materials with specific thermal properties make it possible to optimize solar gain in cold periods and limit it in hot periods, contributing to energy efficiency and creating healthy and comfortable indoor environments. This approach promotes architectural solutions that actively respond to climatic conditions, maximizing human well-being and reducing dependence on mechanical air conditioning systems.[2]

In the current context, solar management within bioclimatic architecture is becoming increasingly relevant due to the global urgency to mitigate climate change and reduce the carbon footprint of the building sector. Architects, urban planners, and policymakers are pushing to incorporate advanced solar strategies and renewable technologies in design and construction, supported by regulations encouraging sustainable practices in new developments and retrofits. However, challenges remain regarding upfront investment, technological availability, and social acceptance of these methods. However, the transition towards a bioclimatic architecture that enhances the use of solar energy for more efficient, comfortable, and environmentally responsible buildings reflects a significant evolution in how built environments are conceived and inhabited.[3]

This article describes studies on how bioclimatic architecture and sustainable design intelligently integrate sunlight, becoming fundamental pillars of contemporary sustainable construction. It emphasizes that, beyond energy efficiency, the optimized incorporation of solar radiation generates habitable spaces that promote human well-being and harmony with the natural environment.

METHOD

A comprehensive narrative review was conducted to analyze the ranalyzingientific literature, consulting Archidaily, Google Scholar, Scielo, and Journal of Architectural Lighting databases. To optimize the search, the terms 'Sun', "Bioclimate," and 'Architecture' were used, combined using the Boolean operators AND and OR, which allowed the scope of the results to be refined and broadened. The search period covered publications between 2019 and 2024, considering papers in English and Spanish. Case reports, interviews, letters to the editor, and theses were deliberately excluded due to their lower level of empirical evidence or specific focus.

The initial strategy generated 15 761 records, 10 000 from Google Scholar, 5 650 from Archidaily, and 111 from Scielo. After eliminating 10 742 duplicates, 4 210 articles were filtered out for not aligning with the study's objective, and 786 were excluded for not meeting the inclusion criteria. Finally, the corpus selected for the analysis comprised 23 relevant articles.

RESULTS

The Sun, a massive star at the center of our planetary system, emits intense electromagnetic radiation ranging from visible light to ultraviolet radiation and is essential for life processes on Earth, such as photosynthesis, the hydrological cycle, and climate regulation.[4] Throughout history, various ancient civilizations, such as the Egyptians, Mayans, and Incas, incorporated the sun as a central element in the design and orientation of their monumental structures, linking architecture to relevant astronomical events such as solstices and equinoxes, reflecting their worldviews and cultural beliefs.[5]

Table 1. Articles consulted

Author	Methodology	Target	Main results
Zalamea-León, Esteban Barragán-Escandón, Antonio	Literature review and qualitative analysis Descriptive and comparative analysis	To examine the current state of solar technology adoption globally, identify barriers and challenges to solar deployment and propose recommendations to promote greater adoption of solar energy as part of the transition to a more sustainable future.	Exploration of design strategies that harness sunlight and heat passively, as well as the use of active technologies such as solar photovoltaic panels and solar heating systems. Studies on how architectural design can improve thermal and visual comfort in buildings.
Rosso, Francisco Bernal	Applied research Theoretical research	Lighting control can improve visual and environmental comfort in indoor spaces.	Analysis of automated and technology-based lighting control systems.
Miceli, Adriana	Field research and case studies	A guide to sustainable architecture, a reliable reference for professionals in the sector.	Innovative strategies and emerging technologies in the field of sustainable architecture.
Ruiz, María Teresa	Qualitative analysis	It explores in depth the role of the sun as a star and its relationship to the Earth and life on the planet.	Detailed description of the structure, composition and dynamics of the sun as a star in the Universe
Behling, Sophia Stefan, Behling	Historical research Analysis of the importance of the sun in the natural world	It highlights the importance of the sun as a source of energy and its influence on architecture throughout history. It provides a comprehensive overview of how buildings have historically been designed to make the most of solar energy, and how this knowledge can be innovatively applied in contemporary architecture.	It formulates positive and innovative proposals for integrating solar architecture into the building construction of the future. This will include suggestions for the use of renewable energies, as well as the promotion of greater collaboration between the industries involved in building processes to encourage greater energy awareness.
Meinel, Aden B. Marjorie P. Meinel	Case study research	A comprehensive introduction to the theory needed to successfully understand and evaluate the characteristics and performance of solar energy systems. Readers are provided with the knowledge and tools necessary to design, implement and maintain efficient and sustainable solar systems.	The book will provide examples and case studies that illustrate the practical application of the theoretical concepts discussed. This will help readers to visualise how they can apply the theory in real situations and obtain successful results in the field of solar energy.
Corbusier, Le	Qualitative analysis.	To provide a profound and persuasive critique of traditional academic architecture, while proposing a renewed and modern approach to architectural design. Constructive renewal in architecture.	Propuesta de una nueva visión arquitectónica. Emoción en el diseño arquitectónico.
Hays, Nathan Badarnah, Lidia Jain, Anuj	Application of biomimetic and computational methods.	Understand how morphological variations in textured surfaces can affect thermal performance and contribute to the efficiency of passive cooling systems in the built environment.	It identifies and proposes generalised evolutionary principles that can serve as a fundamental framework for the design of innovative architectural solutions that utilise the lessons learned from nature.
Lin, Yaolin Yang, Wei Hao, Xiaoli Yu, Changxiong	Comprehensive review of experimental studies	Summarise the research findings of the papers accepted in this special issue, focusing on the use of renewable energy and energy saving technologies in buildings.	It highlights the importance of integrating renewable energy in buildings to improve their energy performance and reduce greenhouse gas emissions.
del Real, Patricio Gyger, Helen	Selection of experts in the field	To provide a comprehensive overview of modern architecture in Latin America, highlighting both well-known and lesser-known projects	Provides crucial information on key case studies, allowing for a deeper understanding of Latin American architecture and its historical and cultural context.

The ancient Egyptians demonstrated remarkable precision in the solar alignment of their constructions, as in the case of the Temple of Abu Simbel, whose orientation allows the sun's rays to penetrate the inner sanctuary during the summer and winter solstices, demonstrating advanced knowledge of the relationship between architecture and solar phenomena.[6] In parallel, in Mesopotamia, the spatial configuration and orientation of buildings were designed to maximize the capture of natural light and solar heat, adapting to climatic conditions to guarantee habitability and thermal comfort, anticipating basic principles of bioclimatic architecture.[7]

For its part, the Inca civilization stood out for its adaptive engineering in high mountain contexts. It used solar radiation and the diversity of microclimates to develop agricultural terraces and passive ventilation and heating systems in its constructions, as in Machu Picchu, which evidences a deep understanding of the interaction between architecture, environment, and human well-being.[8]

In contemporary bioclimatic architecture, the efficient integration of solar energy translates into strategies that optimize natural lighting and reduce dependence on artificial sources, thus promoting healthy and comfortable indoor environments. Proper orientation of spaces, combined with architectural elements such as eaves and solar control devices, maximizes heat gain in winter and minimizes overheating in summer, contributing to the energy efficiency and sustainability of buildings. In addition, incorporating photovoltaic technologies facilitates on-site renewable energy generation, reducing the environmental footprint and supporting climate change mitigation.[9,10]

Globally, solar energy has established itself as a driver of architectural and urban design innovation. In Asia, countries like China are leading the massive implementation of solar technologies, driven by environmental policies and growing urban demands, integrating solar systems into buildings and infrastructure to promote sustainable development.[11] In Europe, nations such as Germany stand out for their energy-efficient buildings and commitment to renewable energy, demonstrating a model to follow in the energy transition.[12] In North America, the United States is expanding its solar capacity in various sectors, from residential to industrial, demonstrating the transformative impact of the sun on its energy matrix.[13]

The integration of renewable sources, including solar, wind, and hydroelectric, into the energy supply of buildings represents a fundamental strategy to reduce dependence on fossil fuels and minimize the building sector's environmental impact, aligning with global sustainability and climate change mitigation goals.[11]

Historically, this search for a functional and rational architecture in the face of social and technological challenges was advanced by visionaries such as Le Corbusier, who in the 20th century promoted a constructive renovation based on efficiency, comfort, and a break with traditional paradigms, laying the foundations for the development of a modern architecture sensitive to the environment and human needs.[14]

CONCLUSIONS

The sun has been a constant source of inspiration and study for humanity, transcending its basic function as a generator of light and heat to become a fundamental element in cultural, scientific, and technological development. In bioclimatic architecture, the sun is a major player that has a decisive influence on the design and functioning of living spaces, promoting energy-efficient and comfortable buildings that are in harmony with the natural environment.

In-depth knowledge of the sun, beyond its physical and astronomical aspects, is essential to understanding its impact on natural and technological systems and enhancing its use in sustainable architecture. This understanding is reflected in developing strategies for integrating sunlight and related phenomena into architectural design, optimizing daylighting and thermal control to improve occupant well-being and reduce energy consumption.

Historically, the influence of industrialization and technological advances have marked a paradigm shift in how housing and public spaces are conceived, emphasizing functionality and efficiency. However, architecture's human and emotional dimensions remain fundamental, driving a vision that combines technical rationality with environmental and social sensitivity. In this context, intelligent incorporation of natural resources such as solar energy is essential for modern, sustainable, and responsible architecture.

Technological innovations in automated lighting control systems and their integration with renewable sources represent a significant advance towards more efficient and healthier buildings. The practical application of these technologies in real projects has demonstrated concrete benefits in optimizing the use of light, reducing energy consumption, and improving environmental comfort.

Architectural planning and design that integrates renewable energies is an indispensable strategy for facing the current climate crisis challenges. Research continues to explore solutions that combine innovative materials and passive systems to maximize buildings' thermal and environmental performance. This holistic approach is key to driving a future where architecture responds to functional needs and actively contributes to the sustainability and resilience of our cities and communities.

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