Bioclimatic Building Design

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Bioclimatic building design emerges as a holistic approach to sustainable architecture that integrates the built environment with natural elements. Bioclimatic building design's capacity to significantly reduce energy consumption, enhance occupant well-being, and shape sustainable behavior has been well documented in existing research.

Keywords: bioclimatic design ; sustainable architecture ; sustainable building

1. Introduction

The world is facing an unprecedented and urgent threat from the dangers of global warming, which calls for swift and well-coordinated action to properly limit its far-reaching and potentially disastrous effects [1]. In recognition of the extreme seriousness of this situation, the international community has established an important and audacious objective: limiting the increase in global temperature to a maximum of 1.5 °C by 2030 [2][3]. The achievement of this bold goal is highly dependent on gaining a comprehensive and detailed comprehension of the energy consumption trends in every economic sector, since each one makes a distinct and substantial contribution to the global carbon footprint [4]. Furthermore, it is critical to put into place and uphold comprehensive energy policies that fiercely support both increased energy efficiency and the broad adoption and integration of cutting-edge, sustainable renewable energy technology [5][6]. Thus, it is imperative to have a thorough and complex recognition of how energy is currently utilized, to identify which industries consume the greatest amount of energy, and to strategically develop and apply methods that have been thoroughly studied to reduce and maximize consumption. As a necessary part of this process, current social attitudes and beliefs regarding energy efficiency and the wider integration of renewable energy production must be carefully examined and questioned [7][8].

Nowadays, global primary energy consumption has exceeded the threshold of 178,000 TWh/year. This huge quantity is allocated nearly equally and proportionately among various economic sectors (i.e., 40% to industry, 32% to buildings, and 28% to transportation), as reported in the energy production and consumption report [9]. In recent decades, scientists and researchers have made great efforts to strengthen and support sustainable energy transitions in a variety of industries. Industries that have a significant impact on the environment, including the iron and steel sector and the cement business utilizing biomass, have been subject to notable and rigorous regulations [10][11][12][13]. Similarly, similar approaches to successfully reduce and limit pollution emissions across multiple infrastructure sectors are also being carefully considered and evaluated [14][15][16][17], including transportation systems [18][19][20], and residential communities [21][22][23]. The strategic and essential deployment of hydrogen as a versatile energy vector is increasingly acknowledged as a key approach for the overall and thorough decarbonization of all sectors, serving as a solution and a feasible alternative to minimize the dependence on fossil fuels [24][25][26]. There are several innovative and useful approaches to producing hydrogen using renewable energy sources and/or wisely recovering energy from waste heat that are currently known and being investigated [27][28][29]. But the effectiveness of these complex plans and solutions is still glaringly obvious: they depend on the development and implementation of careful national policies as well as sophisticated government regulations. The complex environment of the building industry is a striking manifestation of the widespread influence of deeply rooted cultural customs and practices. According to the detailed statistical insights provided by the International Energy Agency's thorough research of the energy balance, buildings are directly responsible for more than one-third of all energy end-use [30]. Because of their very nature and purpose, buildings are clearly recognized as the primary energy consumers, accounting for a staggering 40% of the total energy consumption in the European Union. It becomes abundantly clear that tackling these enormous and complex issues requires a globally coordinated effort, requiring extensive legislative changes, ground-breaking technical developments, and an essential behavioral shift toward the widespread adoption of more environmentally friendly and sustainable practices [31].

Various strategies have been proposed to reduce building energy use and emissions, including stringent building codes, energy efficiency standards for appliances and lighting, smart meters and controls, and on-site renewable energy systems like solar thermal collectors (STC) [32][33][34] and photovoltaics (PV) [35][36][37]. However, one promising but underutilized approach is bioclimatic building design [38][39][40][41]. This concept leverages passive heating, cooling, ventilation, daylighting, and other techniques to minimize the need for mechanical heating, ventilation, and air conditioning (HVAC) and lighting systems. Well-designed bioclimatic buildings can remarkably reduce energy demands while maintaining excellent indoor environmental quality [42][43][44]. The core idea behind bioclimatic architecture is designing buildings tailored to the local climate [45][46]. This involves strategies such as optimizing orientation to maximize southern solar gains [47], careful window placement for daylighting [48], shading and natural ventilation [49], passive solar heating systems [50], evaporative cooling [51], thermal mass storage [52], insulation, and microclimate improvements around the building [53][54]. Such techniques take advantage of natural flows of heat, air, moisture, and light within the environment to maximize occupant comfort [55][56]. This bioclimatic approach was commonly used in vernacular architectural traditions well adapted to local conditions prior to modern heating and cooling technologies [57]. The Mediterranean climate of Cyprus, characterized by hot, dry summers and cooler winters with moderate rainfall, is particularly well suited to bioclimatic principles. Passive solar heating, thermal mass, window placement, and shading can limit winter heating needs, while natural ventilation, evaporative cooling, and shade can reduce summer cooling demands [58][59].

2. Bioclimatic Building Design

Sustainable construction stands as a critical response to the environmental challenges of our time. It seeks to reconcile the built environment with nature and, in doing so, presents innovative approaches such as bioclimatic design, which represents a cornerstone of sustainable architecture.

At its core, bioclimatic design embodies a profound understanding of the intrinsic connection between the built environment and the natural world [35]. It acknowledges that the natural elements, including climate, topography, solar angles, and prevailing winds, can profoundly influence a building's performance. By harnessing these factors, architects and designers can create structures that seamlessly integrate with their surroundings, achieving not only energy efficiency but also harmony with nature [60].

One of the most compelling advantages of bioclimatic design is its inherent ability to drastically reduce energy consumption [61]. Bioclimatic buildings exhibit significantly lower energy needs compared to their conventionally designed counterparts. This substantial energy savings arises from a synergetic blend of passive design strategies, state-of-the-art materials, and innovative technologies [62].

For instance, meticulous attention to insulation and the utilization of high-performance windows and doors drastically minimizes heat transfer, thus diminishing the reliance on mechanical heating and cooling systems. Furthermore, the incorporation of thermal mass in building materials facilitates the moderation of indoor temperatures, further decreasing energy requirements.

Beyond energy efficiency, bioclimatic design prioritizes the well-being and comfort of occupants. Buildings designed with these principles invariably feature abundant natural daylighting, effective cross-ventilation, and thoughtful spatial arrangements [63]. Such design elements collectively create a healthier and more comfortable indoor environment, with quantifiable benefits for the physical and psychological health of occupants. Studies have demonstrated that well-illuminated, naturally ventilated spaces can significantly enhance productivity and overall satisfaction among building users. Different research confirmed that incorporating bioclimatic design strategies, such as integrating natural ventilation and maximizing daylight, leads to significant enhancements in residents' satisfaction and comfort levels [64][65]. Therefore, the bioclimatic design ought to not only enhance comfort but also actively promote sustainable behavior among users, thereby fostering an environment conducive to learning from the built surroundings [66]. Furthermore, a study conducted in the context of Ghadames, Libya, revealed that occupants of older houses expressed thermal satisfaction with indoor comfort conditions, signifying that traditional bioclimatic design strategies can effectively deliver comfort even in the context of desert architecture [67].

Nevertheless, it is imperative to acknowledge that the efficacy of bioclimatic design is contingent upon a constellation of factors. Regional climate conditions, site-specific considerations, and local regulations exert a profound influence on the appropriateness and feasibility of bioclimatic design strategies [68]. What proves successful in one geographical location may necessitate adaptation or alteration when applied elsewhere. Therefore, a nuanced, context-sensitive approach that accounts for the specific conditions of each project is paramount [69].

Indeed, findings from the published scholarly literature underscore the paramount importance of integrating regional climate conditions, site-specific factors, and local regulations into bioclimatic design strategies. The seminal work provides a comprehensive exploration of the bioclimatic approach to architectural regionalism, delving into essential elements like site selection, solar orientation, and the thermal properties of building materials. In a study focused on the Lhasa region of Tibet, there is a meticulous application of bioclimatic design principles, considering factors such as temperature, humidity, solar radiation, and air velocity. The research also includes an analysis of the structure and materials employed in traditional dwellings [70]. Likewise, another study contributes to the field by developing bioclimatic building design charts tailored to various climatic zones in China, offering specific guidance for heating, cooling, and ventilation strategies [71]. Tailored building regulations for warm-dry climates in Mexico were also proposed for extending the applicability of bioclimatic design [72]. These regulations encompass a spectrum of mandatory, optional, and incentivized requirements, all geared towards enhancing energy efficiency, environmental comfort, and the incorporation of low-water-consumption vegetation.

Furthermore, bioclimatic design stands out as a potent catalyst for influencing user behavior towards sustainability, as evidenced by the literature. Barghini (2019) underscores its pivotal role in fostering sustainable behavior among building occupants—a crucial first step towards sustainability [66]. Jamaludin's research (2016) reinforces this perspective, highlighting the profound positive impact of bioclimatic design on user satisfaction and perceptions [73]. His findings emphasize that bioclimatic design not only remains relevant but also excels in meeting contemporary living demands while simultaneously enhancing energy efficiency. Moreover, Jamaludin's earlier work (2013) delves into the tangible benefits of implementing bioclimatic design principles within residential colleges, culminating in increased comfort and contentment among residents [64]. Košir's comprehensive introduction to bioclimatic design (2019) underscores the fundamental importance of harmonizing building design with the environment and inhabitants' needs, ultimately resulting in sustainable structures [74]. These studies collectively reveal that bioclimatic design transcends mere energy efficiency; it positively shapes user behavior by affording comfort and efficiency in built environments. Moreover, the literature suggests that bioclimatic design education and support constitute effective avenues for promoting sustainable and creative architectural design. Kowaltowski's work (2007) intriguingly demonstrates that the constraints imposed by bioclimatic design principles can serve as catalysts for creativity during the design process [75]. Radovic (1996) outlines a curriculum that places a strong emphasis on bioclimatic urban and architectural design [76], while Maciel (2007) stresses the significance of integrating bioclimatic concepts into architects' design philosophy through formal education [77]. Evans (1990) introduces a specialized course for architectural students in Argentina, skillfully incorporating bioclimatic concepts into the design teaching process [78]. This approach allows students to explore the diverse character of designs in various regional contexts. In sum, the literature consistently underscores that bioclimatic design education and support wield considerable influence in promoting both sustainable and creative architectural design practices.

References

1. Jackson, R.B.; Le Quéré, C.; Andrew, R.M.; Canadell, J.G.; Peters, G.P.; Roy, J.; Wu, L. Warning signs for stabilizing global CO2 emissions. Environ. Res. Lett. 2017, 12, 110202.
2. Parikh, K.S.; Parikh, J.K.; Ghosh, P.P. Can India grow and live within a 1.5 degree CO2 emissions budget? Energy Policy 2018, 120, 24–37.
3. Dhar, S.; Pathak, M.; Shukla, P.R. Transformation of India's steel and cement industry in a sustainable 1.5 °C world. Energy Policy 2020, 137, 111104.
4. Panos, E.; Glynn, J.; Kypreos, S.; Lehtilä, A.; Yue, X.; Gallachóir, B.; Daniels, D.; Dai, H. Deep decarbonisation pathways of the energy system in times of unprecedented uncertainty in the energy sector. Energy Policy 2023, 180, 113642.
5. Dhakouani, A.; Znouda, E.; Bouden, C. Impacts of energy efficiency policies on the integration of renewable energy. Energy Policy 2019, 133, 110922.
6. Lohwanitchai, K.; Jareemit, D. Modeling Energy Efficiency Performance and Cost-Benefit Analysis Achieving Net-Zero Energy Building Design: Case Studies of Three Representative Offices in Thailand. Sustainability 2021, 13, 5201.
7. Wen, J.; Okolo, C.V.; Ugwuoke, I.C.; Kolani, K. Research on influencing factors of renewable energy, energy efficiency, on technological innovation. Does trade, investment and human capital development matter? Energy Policy 2022, 160, 112718.
8. Vega, S.H.; van Leeuwen, E.; van Twillert, N. Uptake of residential energy efficiency measures and renewable energy: Do spatial factors matter? Energy Policy 2022, 160, 112659.
9. Hannah Ritchie, H.; Rosado, P.; Roser, M. Energy Production and Consumption). 2020. Available online: https://ourworldindata.org/energy-production-consumption (accessed on 4 December 2023).

10. Kusuma, R.T.; Hiremath, R.B.; Rajesh, P.; Kumar, B.; Renukappa, S. Sustainable transition towards biomass-based cement industry: A review. Renew. Sustain. Energy Rev. 2022, 163, 112503.
11. Wang, X.; Zhang, T.; Luo, S.; Abedin, M.Z. Pathways to improve energy efficiency under carbon emission constraints in iron and steel industry: Using EBM, NCA and QCA approaches. J. Environ. Manag. 2023, 348, 119206.
12. Liu, Y.; Yu, Y.; Huang, Y.; Guan, W. Utilizing the resources efficiency: Evidence from the impacts of media industry and digitalization. Resour. Policy 2024, 88, 104346.
13. Yan, J.; Sheng, Y.; Yang, M.; Yuan, Q.; Gu, X. Local government competition, new energy industry agglomeration and urban ecological total factor energy efficiency: A new perspective from the role of knowledge. J. Clean. Prod. 2023, 429, 139511.
14. Taiwo, R.; Shaban, I.A.; Zayed, T. Development of sustainable water infrastructure: A proper understanding of water pipe failure. J. Clean. Prod. 2023, 398, 136653.
15. Santamaria-Ariza, M.; Sousa, H.S.; Matos, J.C.; Faber, M.H. An exploratory bibliometric analysis of risk, resilience, and sustainability management of transport infrastructure systems. Int. J. Disaster Risk Reduct. 2023, 97, 104063.
16. Barone, G.; Buonomano, A.; Giuzio, G.F.; Palombo, A. Towards zero energy infrastructure buildings: Optimal design of envelope and cooling system. Energy 2023, 279, 128039.
17. Barone, G.; Buonomano, A.; Forzano, C.; Giuzio, G.F.; Palombo, A. Supporting the Sustainable Energy Transition in the Canary Islands: Simulation and Optimization of Multiple Energy System Layouts and Economic Scenarios. Front. Sustain. Cities 2021, 3, 685525.
18. Buonomano, A.; Del Papa, G.; Giuzio, G.F.; Maka, R.; Palombo, A. Advancing sustainability in the maritime sector: Energy design and optimization of large ships through information modelling and dynamic simulation. Appl. Therm. Eng. 2023, 235, 121359.
19. Barone, G.; Buonomano, A.; Del Papa, G.; Maka, R.; Palombo, A. How to achieve energy efficiency and sustainability of large ships: A new tool to optimize the operation of on-board diesel generators. Energy 2023, 282, 128288.
20. Brækken, A.; Gabrielii, C.; Nord, N. Energy use and energy efficiency in cruise ship hotel systems in a Nordic climate. Energy Convers. Manag. 2023, 288, 117121.
21. Caballero, V.; Briones, A.; Coca-Ortegón, A.; Pérez, A.; Barrios, B.; de la Mano, M. Analysis and simulation of an Urban-Industrial Sustainable Energy Community: A use case in San Juan de Mozarrifar using photovoltaic energy. Energy Rep. 2023, 9, 1589–1605.
22. Petrucci, A.; Barone, G.; Buonomano, A.; Athienitis, A. Modelling of a multi-stage energy management control routine for energy demand forecasting, flexibility, and optimization of smart communities using a Recurrent Neural Network. Energy Convers. Manag. 2022, 268, 115995.
23. Wali, S.; Hannan, M.; Ker, P.J.; Rahman, M.A.; Tiong, S.; Begum, R.; Mahlia, T.I. Techno-economic assessment of a hybrid renewable energy storage system for rural community towards achieving sustainable development goals. Energy Strat. Rev. 2023, 50, 101217.
24. Pivetta, D.; Dall'armi, C.; Sandrin, P.; Bogar, M.; Taccani, R. The role of hydrogen as enabler of industrial port area decarbonization. Renew. Sustain. Energy Rev. 2024, 189, 113912.
25. Lee, H. Decarbonization strategies for steel production with uncertainty in hydrogen direct reduction. Energy 2023, 283, 129057.
26. Fetanat, A.; Tayebi, M. Sustainability and reliability-based hydrogen technologies prioritization for decarbonization in the oil refining industry: A decision support system under single-valued neutrosophic set. Int. J. Hydrogen Energy 2023, in Press.
27. Lampe, J.; Menz, S.; Akinci, K.; Böhm, K.; Seeger, T.; Fend, T. Optimizing the operational strategy of a solar-driven reactor for thermochemical hydrogen production. Int. J. Hydrogen Energy 2022, 47, 14453–14468.
28. Costa, M.; Maka, R.; Marra, F.S.; Palombo, A.; Prati, M.V. Assessing techno-economic feasibility of cogeneration and power to hydrogen plants: A novel dynamic simulation model. Energy Rep. 2023, 10, 1739–1752.
29. Barone, G.; Buonomano, A.; Forzano, C.; Giuzio, G.; Palombo, A. Energy performance assessment of a solar-driven thermochemical cycle device for green hydrogen production. Sustain. Energy Technol. Assess. 2023, 60, 103463.
30. IEA. World Energy Outlook 2023; IEA: Paris, France, 2023; Available online: https://www.iea.org/reports/world-energy-outlook-2023 (accessed on 4 December 2023).
31. Giacosa, G.; Walker, T.R. A policy perspective on Nova Scotia's plans to reduce dependency on fossil fuels for electricity generation and improve air quality. Clean. Prod. Lett. 2022, 3, 100017.

32. Barone, G.; Buonomano, A.; Palmieri, V.; Palombo, A. A prototypal high-vacuum integrated collector storage solar water heater: Experimentation, design, and optimization through a new in-house 3D dynamic simulation model. Energy 2022, 238, 122065.
33. Kalogirou, S.; Tripanagnostopoulos, Y.; Souliotis, M. Performance of solar systems employing collectors with colored absorber. Energy Build. 2005, 37, 824–835.
34. Norton, B. Anatomy of a solar collector: Developments in Materials, Components and Efficiency Improvements in Solar Thermal Collector Systems. Refocus 2006, 7, 32–35.
35. Vassiliades, C.; Michael, A.; Savvides, A.; Kalogirou, S. Improvement of passive behaviour of existing buildings through the integration of active solar energy systems. Energy 2018, 163, 1178–1192.
36. Karytsas, S.; Vardopoulos, I.; Theodoropoulou, E. Factors Affecting Sustainable Market Acceptance of Residential Microgeneration Technologies. A Two Time Period Comparative Analysis. Energies 2019, 12, 3298.
37. Barone, G.; Vassiliades, C.; Elia, C.; Savvides, A.; Kalogirou, S. Design optimization of a solar system integrated double-skin façade for a clustered housing unit. Renew. Energy 2023, 215, 119023.
38. Naboni, E.; Malcangi, A.; Zhang, Y.; Barzon, F. Defining the Energy Saving Potential of Architectural Design. Energy Procedia 2015, 83, 140–146.
39. Elaouzy, Y.; El Fadar, A. Impact of key bioclimatic design strategies on buildings' performance in dominant climates worldwide. Energy Sustain. Dev. 2022, 68, 532–549.
40. Elaouzy, Y.; El Fadar, A. Sustainability of building-integrated bioclimatic design strategies depending on energy affordability. Renew. Sustain. Energy Rev. 2023, 179, 113295.
41. Altan, H.; Ozarisoy, B. An Analysis of the Development of Modular Building Design Elements to Improve Thermal Performance of a Representative High Rise Residential Estate in the Coastline City of Famagusta, Cyprus. Sustainability 2022, 14, 4065.
42. Theokli, C.; Elia, C.; Markou, M.; Vassiliades, C. Energy renovation of an existing building in Nicosia Cyprus and investigation of the passive contribution of a BIPV/T double façade system: A case-study. Energy Rep. 2021, 7, 8522–8533.
43. Italos, C.; Patsias, M.; Yiangou, A.; Stavrinou, S.; Vassiliades, C. Use of double skin façade with building integrated solar systems for an energy renovation of an existing building in Limassol, Cyprus: Energy performance analysis. Energy Rep. 2022, 8, 15144–15161.
44. Stavrakakis, G.; Koukou, M.; Vrachopoulos, M.; Markatos, N. Natural cross-ventilation in buildings: Building-scale experiments, numerical simulation and thermal comfort evaluation. Energy Build. 2008, 40, 1666–1681.
45. Dogkas, G.; Koukou, M.K.; Konstantaras, J.; Pagkalos, C.; Lymperis, K.; Stathopoulos, V.; Coelho, L.; Rebola, A.; Vrachopoulos, M.G. Investigating the performance of a thermal energy storage unit with paraffin as phase change material, targeting buildings' cooling needs: An experimental approach. Int. J. Thermofluids 2020, 3–4, 100027.
46. Xydis, G. Exergy Analysis in Low Carbon Technologies—The Case of Renewable Energy in the Building Sector. Indoor Built Environ. 2009, 18, 396–406.
47. Benincá, L.; Sánchez, E.C.; Passuello, A.; Leitzke, R.K.; da Cunha, E.G.; Barroso, J.M.G. Multi-objective optimization of the solar orientation of two residential multifamily buildings in south Brazil. Energy Build. 2023, 285, 112838.
48. Ahmed, A.E.; Suwaed, M.S.; Shakir, A.M.; Ghareeb, A. The impact of window orientation, glazing, and window-to-wall ratio on the heating and cooling energy of an office building: The case of hot and semi-arid climate. J. Eng. Res. 2023.
49. Zhong, H.-Y.; Sun, Y.; Shang, J.; Qian, F.-P.; Zhao, F.-Y.; Kikumoto, H.; Jimenez-Bescos, C.; Liu, X. Single-sided natural ventilation in buildings: A critical literature review. Build. Environ. 2022, 212, 108797.
50. Chen, Y.; Chen, Z.; Wang, D.; Liu, Y.; Zhang, Y.; Liu, Y.; Zhao, Y.; Gao, M.; Fan, J. Co-optimization of passive building and active solar heating system based on the objective of minimum carbon emissions. Energy 2023, 275, 127401.
51. Mazzei, P.; Palombo, A. Economic evaluation of hybrid evaporative technology implementation in Italy. Build. Environ. 1999, 34, 571–582.
52. Chen, Y.; Xu, P.; Chen, Z.; Wang, H.; Sha, H.; Ji, Y.; Zhang, Y.; Dou, Q.; Wang, S. Experimental investigation of demand response potential of buildings: Combined passive thermal mass and active storage. Appl. Energy 2020, 280, 115956.
53. Strasszer, D.; Xydis, G. CFD-Based Wind Assessment for Suburban Buildings. The Case Study of Aarhus University, Herning Campus. Front. Energy Res. 2020, 8, 539095.
54. Zorpas, A.A.; Skouroupatis, A. Indoor air quality evaluation of two museums in a subtropical climate conditions. Sustain. Cities Soc. 2016, 20, 52–60.

55. Watson, D. Bioclimatic Design. In Sustainable Built Environments; Encyclopedia of Sustainability Science and Technology Series; Loftness, V., Ed.; Springer: New York, NY, USA, 2020.

56. Panagiotopoulos, N.; Lekatou, A.; Agrafioti, K.; Prouskas, C.; Koukou, M.; Konstantaras, J.; Lymperis, K.; Vrachopoulos, M.; Evangelakis, G. Anticorrosive AlN coatings for heat exchangers in thermal energy storage systems. Therm. Sci. Eng. Prog. 2023, 43, 102014.

57. Tsilika, E. “Sun and Shadow:” Exploring Marcel Breuer’s Basic Design Principle. Arch. Cult. 2021, 9, 335–360.

58. Kaliakatsos, D.; Nicoletti, F.; Paradisi, F.; Bevilacqua, P.; Arcuri, N. Evaluation of Building Energy Savings Achievable with an Attached Bioclimatic Greenhouse: Parametric Analysis and Solar Gain Control Techniques. Buildings 2022, 12, 2186.

59. Alwetaishi, M.; Balabel, A.; Abdelhafiz, A.; Issa, U.; Sharaky, I.; Shamseldin, A.; Al-Surf, M.; Al-Harthi, M.; Gadi, M. User Thermal Comfort in Historic Buildings: Evaluation of the Potential of Thermal Mass, Orientation, Evaporative Cooling and Ventilation. Sustainability 2020, 12, 9672.

60. Aghimien, E.I.; Li, D.H.W.; Tsang, E.K.-W. Bioclimatic architecture and its energy-saving potentials: A review and future directions. Eng. Constr. Arch. Manag. 2022, 29, 961–988.

61. Beccali, M.; Strazzeri, V.; Germanà, M.; Melluso, V.; Galatioto, A. Vernacular and bioclimatic architecture and indoor thermal comfort implications in hot-humid climates: An overview. Renew. Sustain. Energy Rev. 2018, 82, 1726–1736.

62. Elaouzy, Y.; El Fadar, A. Energy, economic and environmental benefits of integrating passive design strategies into buildings: A review. Renew. Sustain. Energy Rev. 2022, 167, 112828.

63. Couvelas, A. Bioclimatic building design theory and application. Procedia Manuf. 2020, 44, 326–333.

64. Jamaludin, A.A.; Keumala, N.; Ariffin, A.R.M.; Hussein, H. Satisfaction and perception of residents towards bioclimatic design strategies: Residential college buildings. Indoor Built Environ. 2014, 23, 933–945.

65. Hussein, H.; Jamaludin, A.A. POE of Bioclimatic Design Building towards Promoting Sustainable Living. Procedia Soc. Behav. Sci. 2015, 168, 280–288.

66. Barghini, L.; Yashiro, T. How can bioclimatic design foster diversification of low-energy building strategies in the next future?—Design for long-term learning process in residential building. IOP Conf. Ser. Earth Environ. Sci. 2019, 294, 012074.

67. Alabid, J.; Taki, A. Bioclimatic housing design to desert architecture: A case study of Ghadames, Libya. HVAC&R Res. 2014, 20, 760–769.

68. Kanteraki, A.E.; Kyriakopoulos, G.L.; Zamparas, M.; Kapsalis, V.C.; Makridis, S.S.; Mihalakakou, G. Investigating Thermal Performance of Residential Buildings in Marmari Region, South Evia, Greece. Challenges 2020, 11, 5.

69. Vardopoulos, I.; Vannas, I.; Xydis, G.; Vassiliades, C. Homeowners’ Perceptions of Renewable Energy and Market Value of Sustainable Buildings. Energies 2023, 16, 4178.

70. Zhang, X.; Lian, Z. The Bioclimatic Design Approach to Plateau Region Buildings: Case of the Lhasa. Procedia Eng. 2015, 121, 2044–2051.

71. Yang, L.; Lam, J.C.; Liu, J. Bioclimatic Building Designs for Different Climates in China. Arch. Sci. Rev. 2005, 48, 187–194.

72. Ochoa, J.M.; Marincic, I.; Alpuche, M.G.; Duarte, E.A.; Gonzalez, I.; Huelz, G.; Barrios, G. Cost Benefit Energy Analysis of the Building Envelope Systems with Ener-Habitat. Energy Procedia 2014, 57, 1792–1797.

73. Jamaludin, A.A.; Hussein, H.; Keumala, N.; Ariffin, A.R.M. Preferences of student residents towards sustainability with the concept of bioclimatic design. Plan. Malays. J. 2016, 14, 145–156.

74. Košir, M. Climate Adaptability of Buildings: Bioclimatic Design in the Light of Climate Change; Springer: Cham, Switzerland, 2019.

75. Kowaltowski, D.C.C.K.; Labaki, L.C.; De Paiva, V.T.; Bianchi, G.; Mösch, M.E. The creative design process supported by the restrictions imposed by bioclimatic and school architecture: A teaching experience. In Proceedings of the 2nd PALENC Conference, and 28th AIVC Conference: Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century, Crete, Greece, 27–29 September 2007; pp. 577–581.

76. Radovic, D. Bioclimatic design as the core of Environment Programmes. Energy Build. 1996, 23, 271–275.

77. Maciel, A.A.; Ford, B.; Lamberts, R. Main influences on the design philosophy and knowledge basis to bioclimatic integration into architectural design—The example of best practices. Build. Environ. 2007, 42, 3762–3773.

78. Evans, J.M.; de Schiller, S. Bridging the gap between climate and design: A bioclimatic design course for architectural students in Argentina. Energy Build. 1990, 15, 43–50.