

Climate-Responsive Design for Sustainable Construction: Passive Strategies in Domestic Architecture Supporting Sustainability

Nahed Chakouf

Department of College of Arts and Creative Enterprise, Zayed University, Dubai, United Arab Emirates,

Nahed@researchergroup.co

Follow this and additional works at: <https://commons.yildiz.edu.tr/jscmt>



Part of the [Biomaterials Commons](#), [Chemical Engineering Commons](#), [Civil and Environmental Engineering Commons](#), [Engineering Science and Materials Commons](#), [Materials Science and Engineering Commons](#), [Mechanical Engineering Commons](#), and the [Molecular, Cellular, and Tissue Engineering Commons](#)

Recommended Citation

Chakouf, Nahed (2026) "Climate-Responsive Design for Sustainable Construction: Passive Strategies in Domestic Architecture Supporting Sustainability," *Journal of Sustainable Construction Materials and Technologies*: Vol. 11: Iss. 3, Article 1.

<https://doi.org/10.29187/2458-973X.1227>

Available at: <https://commons.yildiz.edu.tr/jscmt/vol11/iss3/1>

This Research Article is brought to you for free and open access by YTU Press. It has been accepted for inclusion in Journal of Sustainable Construction Materials and Technologies by an authorized editor of YTU Press.



RESEARCH ARTICLE

Climate-Responsive Design for Sustainable Construction: Passive Strategies in Domestic Architecture Supporting Sustainability

Nahed Chakouf 

Department of College of Arts and Creative Enterprise, Zayed University, Dubai, United Arab Emirates

ABSTRACT

This study explores climate-responsive design in domestic architecture, focusing on the application and effectiveness of passive strategies across various climatic regions, including the UK, hot-arid, tropical, and cold climates. A qualitative comparative case study method was used to explore different passive design strategies, integration of sustainability, procurement, the coordination of stakeholders, and compliance with regulations in residential architectural projects under varying climate conditions. Drawing from a combination of historical case studies and original architectural projects, the research evaluates how spatial configuration, material selection, solar orientation, shading, ventilation, and insulation are optimized to achieve thermal comfort and energy efficiency. In temperate maritime climates like the UK, strategies emphasize airtight construction, high-performance insulation, and mechanical ventilation, in compliance with regulatory frameworks such as the UK Building Regulations Part L and the Future Homes Standard. By contrast, international case studies demonstrate context-sensitive approaches such as wind towers, open courtyards, elevated structures, and thermal massing tailored to local conditions. Through comparative analysis, the research highlights how regulatory constraints, climatic variables, and traditional design practices shape passive architecture. The findings reinforce that passive design enhances energy efficiency and occupant comfort and supports long-term climate resilience. This study contributes to the discourse on sustainable architecture by offering adaptable, regulation-aware passive design models that can be implemented globally, especially in domestic settings aiming to reduce operational carbon emissions while enhancing indoor environmental quality.

Keywords: Climate-adaptive design, Sustainable construction, Passive design strategies, Thermal comfort, Vernacular architecture, Energy efficiency in buildings, Climate-responsive architecture

1. Introduction

The increasing urgency of environmental sustainability has placed climate-responsive design at the forefront of contemporary architectural discourse [1]. As concerns about climate change [2], energy consumption [3], and resource depletion intensify [4], the built environment must evolve to address these challenges. This method relies heavily on passive design strategies, which utilize the inherent properties of materials, spatial planning, and environmental forces to minimize energy consumption [5].

Unlike conventional buildings that depend on artificial heating, cooling, and lighting systems, climate-responsive structures harness natural resources to maintain thermal comfort and functionality [6].

Climate-responsive design extends beyond environmental benefits, improving economic and social sustainability [7]. The RIBA Climate Guide highlights architects' role in integrating ecological considerations into design, ensuring energy-efficient, low-maintenance homes that enhance occupant well-being [8, 9]. Integration of these climate-responsive strategies also fits within the global sustainability

Received 27 August 2025; revised 27 June 2026; accepted 27 June 2026.
Available online 3 July 2026

E-mail address: Nahed@researchergroup.co (N. Chakouf).

<https://doi.org/10.29187/2458-973X.1227>

2458-973X/© 2026 Published by Yıldız Technical University Press, İstanbul, Türkiye. This is an open access article under the CC BY-NC 4.0 Licence (<https://creativecommons.org/licenses/by-nc/4.0/>).

goals of reducing greenhouse gas emissions and promoting eco-friendly urban development [10]. With climate change increasing that delivers extreme weather patterns frequently, designing structures resilient to changing temperatures and unusual environmental problems has become a critical aspect [11].

It goes without saying that architects are key players involved in implementing and developing climate-responsive solutions. They are not merely involved in selecting aesthetic and structural considerations but also in choosing materials, spatial organization, and building techniques that optimize energy performance [12]. A thorough knowledge of climate, sun path, wind patterns, and building materials' thermal properties is needed to achieve this [13, 14]. Early integration of passive design principles into the planning process greatly boosts energy efficiency and sustainability of domestic architecture [15, 16]. In order to maintain a high quality of life, it is important to provide a comfortable thermal environment in a residential location where the occupants spend much time. Also, environmentally conscious construction methods can divert natural resources from depletion and waste from being created, thus increasing the sustainable built environment [17].

Architectural strategies based on passive concepts are more important in domestic architecture because occupants directly sense the environmental conditions [18]. Values from traditional building practices worldwide have much to give to climate-responsive architecture [19]. Passive design elements were found in indigenous and vernacular architecture that were typically refined over centuries to suit the local climatic conditions [20]. These solutions lay the foundation for modern climate-responsive architecture, from the wind towers of Eastern homes to the thick walls of traditional dwellings in hot and arid regions. From such precedents, contemporary architects can learn and incorporate both traditional and innovative ways of designing residential buildings so that they live well and simultaneously maximize the energy efficiency of buildings [12, 21, 22].

Due to increasing pressure of global warming, it is important to combine sustainable architectural practices to achieve an efficient and resilient built environment. Climate-responsive design is not only a method of environmental impact reduction but also a way toward strong, long-term, cost-effective, and functional architecture in residential spaces [23]. Previous studies defined passive strategies, but they were general or did not include these case studies for the UK-based architecture, particularly [23, 24]. This current study fulfilled the existing gap and passive

strategies offered to architects, the way forward to embrace greenhouse design according to the passing nature and harmoniously meet the contemporary necessities of the socioeconomy. With the recent developments in the field of traditional knowledge embracing the current trends in technological innovations, the field of climate-responsive design opens up an opportunity to alter the image of domestic architecture in the future, not only in ensuring energy efficiency but also in designing comfortable, adaptable and characterful homes that fit well into the natural environment [25].

This study demonstrated the practical applications and benefits of climate-responsive design and how analysis of successful thermal massing, solar orientation, shading and ventilation can be used. Through a comparative investigation of several projects across numerous locations, new solutions will be developed that pertain to distinct climatic contexts and passive architectural responses, which may be adapted to different environmental conditions. An example of how climate change adaptation strategies chosen by different regions tailored to their distinctive climatic challenges are applied in current architectural projects, as well as how these strategies were adapted to local climatic conditions, is also presented in the other case studies. This study seeks to furnish a unified idea about passive design strategies as a way of climate-responsive design by exploring the subject's theoretical and pragmatic aspects.

This study aimed to explore the possibilities of climate-responsive architecture through comparing examples from UK residential projects and international projects based in hot-arid, tropical, and cold climates. Through the inclusion of international case studies, it is possible to understand more about how passive architectural design techniques can be adapted within a variety of climatic environments.

1.1. Climate context and architectural response

Architectural design responsive to climatic conditions should achieve comfort, energy efficiency, and sustainability [26]. There are differences between climates, and each poses problems and needs the design adaptation to achieve the optimum indoor comfort, at least with minimum use of the mechanicals.

Furthermore, the increasing frequency of extreme weather events, such as heatwaves in the UK and severe winter conditions in colder regions, makes climate-responsive design a key strategy for enhancing resilience [27, 28]. In regard to this, passive strategies have a major role to play in climate resilience, serving to help buildings adapt to warming

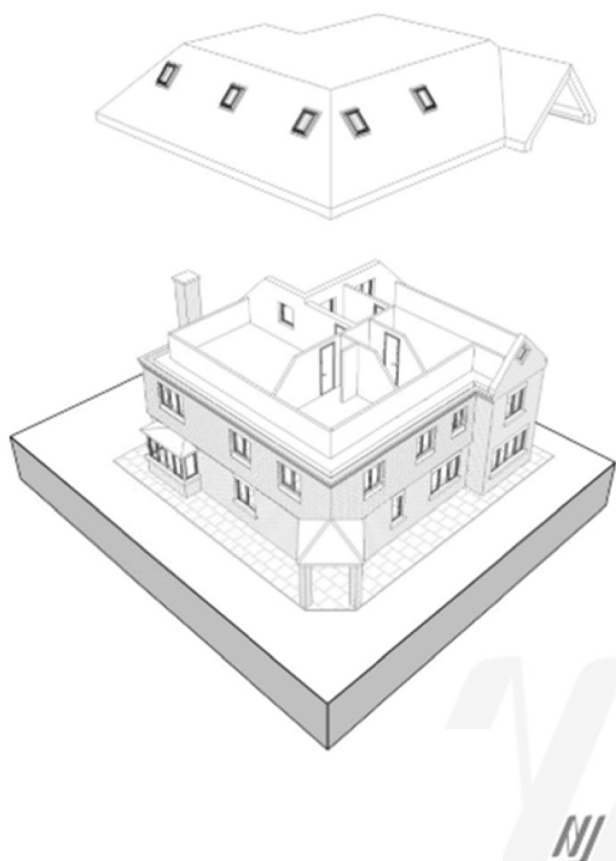


Fig. 1. 3D design of a Roof Remodel.

temperatures, extreme weather events and changing conditions of the environment. Architects can design a structure to withstand long term climatic changes with thermal comfort and functionality by incorporating principles of urban resilience such as energy demand reduction and overheating risk mitigation [29]. By applying these passive cooling techniques, Optimum shading, Cross ventilation, Thermal mass, etc., the sustainable solution is to mitigate overheating risks in domestic buildings. In addition, climate resilience in the built environment must occur with little change in the physical infrastructures and requires the retrofitting of existing housing stock along with passive strategies to reduce energy demand in the existing stock without drastic changes, as shown in Fig. 1.

Conditions in hot, arid climates necessitate mitigation strategies for extreme heat, ventilation enhancement, and thermal buffering [30]. However, in tropical climates, solutions are needed to overcome humidity issues and promote airflow, whereas, in cold climates, attention is needed to insulation and heat retention [31]. Through a careful selection of materials, spatial configuration, and passive tech-

niques [32], architects can create climate-responsive buildings that enhance both functionality and efficiency [6, 29]. Additionally, the retrofitting of existing buildings presents an opportunity to integrate passive strategies into older housing stock, particularly in the UK, where a significant portion of the built environment predates modern sustainability standards [22]. By improving insulation, incorporating shading devices, and enhancing natural ventilation, older homes can be adapted to contemporary energy efficiency requirements while reducing their environmental impact [31, 33]. The second section examines case studies and personal architectural projects that espouse passive strategies appropriate for their particular climate.

1.2. Hot & arid climates

Hot and arid climates experience high solar radiation, minimal precipitation, and extreme diurnal temperature variations, requiring passive design strategies that prioritize thermal mass, natural ventilation, and shading [34]. Buildings in these regions use thick walls with high thermal mass such as adobe, rammed earth, or concrete to absorb heat during the day and release it at night, regulating indoor temperatures naturally [35, 36]. Deep overhangs, narrow openings, and courtyard designs reduce direct solar exposure while promoting cross-ventilation to enhance comfort [37].

A well-known example of desert modernism is the Kaufmann House in Palm Springs, USA and shows how architecture can be adopted to such extreme climatic conditions. The deep overhangs protect the interiors from harsh sunlight and offer a controlled daylight penetration. Natural ventilation from passive cooling is promoted through an open courtyard layout. The thermal buffer of the material palette is made of concrete, glass, and steel to gain excessive heat during the day but radiate stored warmth at night. Strategic cross ventilation, as well as shading devices, contribute to the thermal control both inside the house and with the arid environment, and show a good response.

In Egypt, the Akil Sami House is a modern exhibition of traditional mud brick construction with an excellent thermal mass that regulates indoor temperatures. The walls on the day that absorb and store the heat which keeps the interior cool and the heat is released gradually at night when the external temperatures fall. Wind towers are also found on the house: historic passive ventilation method which allows cool air in and removes warm air improving the house's ventilation and comfort. However, although

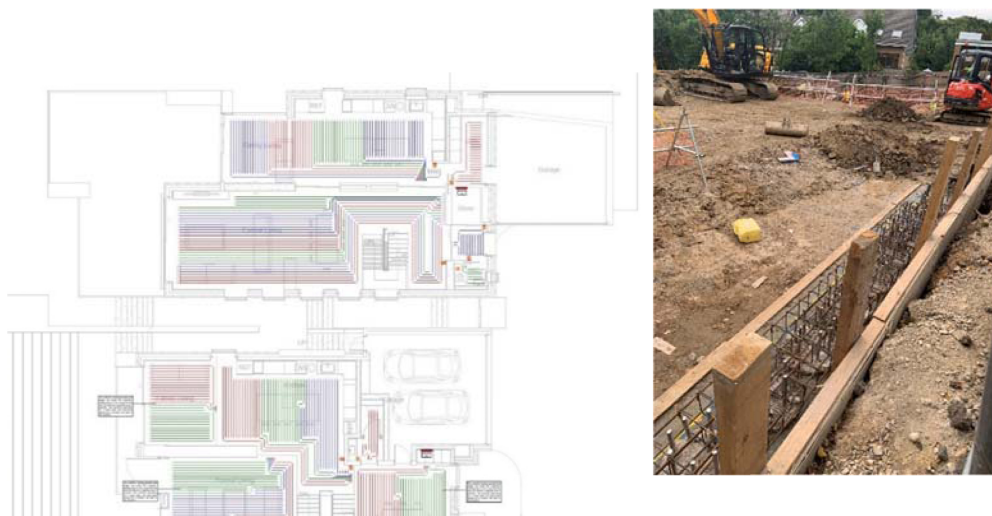


Fig. 2. Design enhances thermal comfort and supports low-temperature heating systems, aligning with energy efficiency standards required by the UK Building Regulations and the Future Homes Standard.

wind towers have evolved from these ancient forms, they are still a highly effective and sustainable cooling option in modern eco homes in arid climates.

Deep overhangs, high thermal mass and cross ventilation are used in the Kaufmann House and Akil Sami House to create thermal comfort under extreme heat. However, Bathgate Road combines cavity wall construction with PIR insulation, and this is to minimize heat transfer. RT160 Levan Linear and RT153 Mid Grey Linear bricks are used for durability and moisture resistance. The project adheres to BS 8000-3 standards of weather resilience and longevity. In arid climates, buildings attempt to achieve ventilation and heat absorption delay; and in temperate climates, air tightness and moisture control is promoted as a form of heat loss prevention.

This serves to demonstrate how passive design strategies can avoid extremity of climate in hot, arid environment through material, orientation and ventilation strategies to achieve energy efficiency and thermal comfort.

1.3. Temperate maritime climate: The UK context

In the UK, as in temperate maritime climates around the world, buildings have to balance heat retention in winter with overheating prevention in summer, as shown in Fig. 2 of the design, enhances thermal comfort and supports low-temperature heating systems. However, temperate strategies are different from hot arid environments where thermal mass and natural ventilation are key, with very high insulation, very airtightness and controlled solar gain [38, 39]. Two projects that exemplify climate-responsive

architecture in the UK are Bathgate Road and 41 Seymour Road, both integrating passive strategies, sustainable materials, and renewable technologies to enhance energy efficiency while complying with UK regulations.

The Bathgate Road project in London incorporates 100mm PIR cavity wall insulation with a thermal conductivity of $0.022 \text{ W/m}\cdot\text{K}$ to minimize heat loss. Expanded polystyrene (EPS) insulation in cavity walls further enhances thermal efficiency.

Insulated glazing with a U-value of $1.6 \text{ W/m}^2\text{K}$ reduces heat loss in winter and prevents overheating in summer. Airtight membranes and vapor control layers minimize uncontrolled heat loss while meeting Future Homes Standard targets. Ventilated cavity walls and controlled shading optimize indoor comfort across seasonal variations. The rainwater drainage systems prevent waterlogging and address increased precipitation due to climate change. Durable clay facing bricks, such as RT160 Levan Linear and RT153 Mid Grey Linear, with low water absorption of 12% and high compressive strength of 45 N/mm^2 , ensure moisture control and longevity.

The project 41 Seymour Road, in the UK, incorporates several strategies with climate responsiveness and energy-efficiency, all in line with the UK sustainability regulations. External shading devices help keep heat out in summer and maximize the heat gain in the winter, thanks to the south facing glazing. The use of high performance insulation and airtight detailing further enhances the thermal efficiency as required by Part L of the UK Building Regulations. Conforming to sustainable design targets and the UK Future Homes Standard, PV panels have been fitted

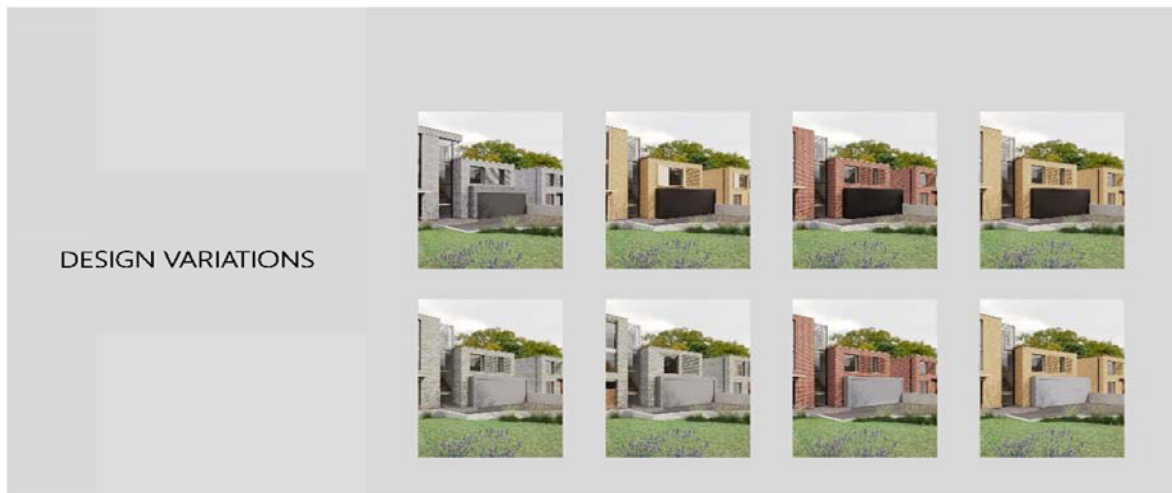


Fig. 3. External façade of Bathgate Road showing durable clay brickwork and PIR-insulated cavity construction. The robust envelope enhances moisture resistance and thermal performance.

as part of the Wimbledon loft conversion as shown in Fig. 4.

In Fig. 4, the Wimbledon loft conversion project illustrates the seamless incorporation of solar PV systems into residential retrofits. The PV array, carefully integrated with the roofline, exemplifies renewable energy adoption in urban domestic architecture. This

complements other passive strategies such as airtight insulation and shading, reducing operational carbon emissions and aligning with Part L of UK Building Regulations.

The drawings in Fig. 5 illustrate how spatial organisation, deep insulation zones, and subterranean thermal mass contribute to a passive design strategy



Fig. 4. Photovoltaic (PV) panels were installed during the Wimbledon loft conversion, demonstrating the integration of renewable energy technologies in line with the UK Future Homes Standard and sustainable design targets. 41 Seymour Road project.

that enhances airtightness, acoustic separation, and long-term energy performance. The basement pool and service areas are strategically positioned to stabilise internal temperatures, while the sectional layering demonstrates efficient zoning of conditioned spaces aligned with UK Building Regulations Part L.

The technical development of Bathgate Road reinforces its passive and climate-responsive design ethos. The use of a basement with embedded service zones and a pool supports passive cooling and acoustic buffering. Meanwhile, the compact vertical zoning and generous insulation depths visible in section demonstrate how airtightness, spatial hierarchy, and construction detailing work together to meet the energy targets defined by the Future Homes Standard.

The 41 Seymour Road project in the UK employs south-facing glazing to maximize solar heat gain in winter, reducing heating demand. External shading and deep overhangs prevent summer overheating while maintaining daylight access. High-performance insulation and airtight detailing align with UK Part L regulations for low-energy consumption. Green landscaping elements, such as permeable paving and planted areas, improve water drainage and biodiversity. The use of PVC window frames enhances thermal efficiency, durability, and recyclability. The project also integrates a solar PV system as shown in Fig. 6, with 4.3 kWp Canadian Solar 430W Heterojunction HiHero panels, providing on-site renewable energy generation.

Energy self-sufficiency is improved with a Solis 4.0 kW inverter and battery storage as well, so excess solar can be stored for later use. The solar panel mounting system is mechanically fixed to minimize impact of structure for long term solar energy harvest-

ing. Mechanical ventilation heat recovery (MVHR) system is an optimised mechanical ventilation system with which you can reduce the demand for heating and improve the indoor air quality. Moreover, integration of rainwater harvesting helps cut down on use of mains water and increase sustainability.

The system in Fig. 6, enables on-site energy storage and self-sufficiency, reducing grid dependency and operational carbon emissions. The integration of Tesla Powerwall technology complements passive strategies by storing excess solar energy, optimizing usage throughout the day, and aligning with sustainable energy models for residential architecture. Moreover, the pitched roof incorporates layered insulation and timber-frame construction to enhance thermal efficiency and reduce heat loss as shown in Fig. 7.

1.4. Regulatory compliance & climate adaptation

Aligned with UK Building Regulations Part L, requiring high energy efficiency standards and Future Homes Standard to achieve operational carbon emissions reductions of 75–80% by 2025, these strategies also support the minimum requirement for sustainability and increase living comfort for the occupant. The two projects show a prioritization of insulation, airtightness and moisture control over thermal mass and natural ventilation in temperate climates, which are dominant strategies in hotter regions.

This newly built home in Fig. 8 demonstrates climate-responsive detailing through durable materials, airtight envelope design, and solar orientation strategies in line with UK Building Regulations Part L.

Another thing is, 41 Seymour Road also includes renewable energy solutions like solar PV and battery storage, which limits dependence upon using grid electricity and also cut down on carbon emissions, that set as an example of sustainable development of residential property in UK. Bathgate Road serves as an example of airtight construction and advanced insulation techniques which illustrates how passive strategies can be refined in ways that meet existing sustainability standards.

1.5. Tropical climates

Hot, wet, humid climates such as tropical regions a passive design and aim to maximize the airflow, limit the solar heat gain and avoid moisture accumulation [32]. Casa de Vidro in Brazil is a good example of tropical climate adaptation. The structure is elevated on stilts pushed up, allowing air to circulate underneath to reduce ground moisture and promote passive cooling. Extensive use of glass facades for

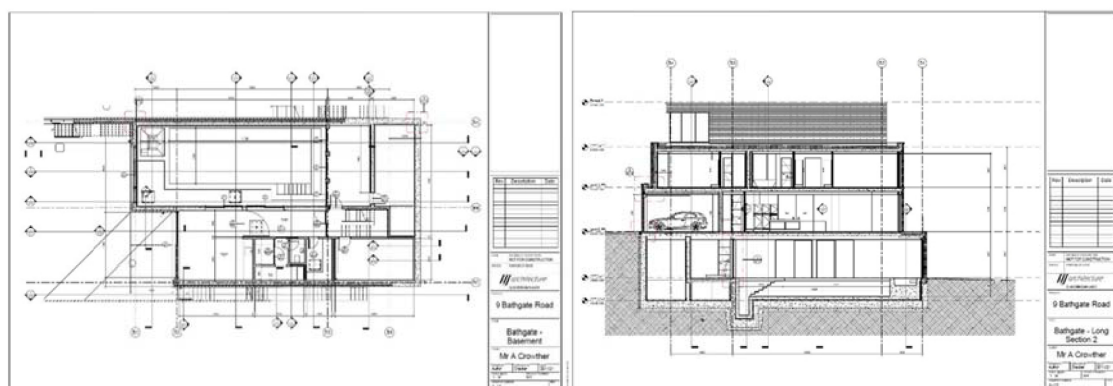


Fig. 5. Technical drawings from Bathgate Road showing the basement plan (left) and a long section through the full building (right).



Fig. 6. Tesla Powerwall battery and solar inverter installed at Seymour Road project. 41 Seymour Road.

natural light is done, and strategic shading devices are required to prevent overheating [40]. While the project at Seymour Road in the UK is not in a tropical setting, but it applies similar passive strategies to improve energy efficiency. In this case, the open plan helps promote cross ventilation, alleviating the need for artificial cooling. Operating windows let natural air flow, bring in fresh air to keep the insides cool and protect from heat gain due to deep overhangs [8]. In addition, solar photovoltaic (PV) panels help to provide for renewable energy generation [41]. Additional climate-responsive techniques suitable for the tropical region include Santillana Beach House in Mexico. Open courtyards are also featured in the design to induce stack ventilation, allowing warm air to rise and exit spaces and air to enter living spaces [42]. Together, these elements create a comfortable indoor environment with weak dependence on mechanical systems [43].

1.6. Cold climates

Due to the cold nature of the climates, the major aim of architectural strategies is to enhance heat retention, heat insulation, and regulated ventilation [44]. In such environments, buildings must retain

heat by losing heat as little as possible when extreme temperatures occur while gaining heat as much as possible through natural sources of solar heat in order to have optimum energy performance [33].

Cold climate architecture shows itself in an outstanding example of the Bianchi house in Switzerland. Thick brick walls provide High thermal insulation in this residence to maintain indoor temperatures [45]. To make up for that, the design presents as few windows as possible, with minimal openings, since further heat escape is reduced, and well-insulated windows optimise daylight penetration while not compromising on warmth [46, 47]. So that the occupants do not suffer from uncomfortable heat in the winter or from too much heat in the summer, a careful balance between insulation and daylighting is made.

The Bianchi House in Switzerland is a well-designed passive thermal solution for a high performance cold climate house. The building envelope is built using a high-density and thick brick masonry wall, which helps to maximize thermal mass and minimize heat transfer and to reduce the temperature fluctuations inside during extreme winter conditions. Heat losses are also minimized by limiting the size and number of fenestrations (windows) and are intentionally a small percentage of the total wall area to control conductive and convective heat losses. High-performance double or triple-glazed insulated units are used to enhance thermal resistance when openings are made, without compromising the controlled daylighting [48]. The architectural composition demonstrates a conscious emphasis on retaining heat rather than using a lot of glazing in a temperate way. The spatial planning is also optimized for reduced thermal bridging and compact form factor for optimization of energy efficiency [49]. These passive design features together help to provide thermal comfort for the occupants even at climatic extremes, without undue dependence on mechanical heating systems, aligning with the

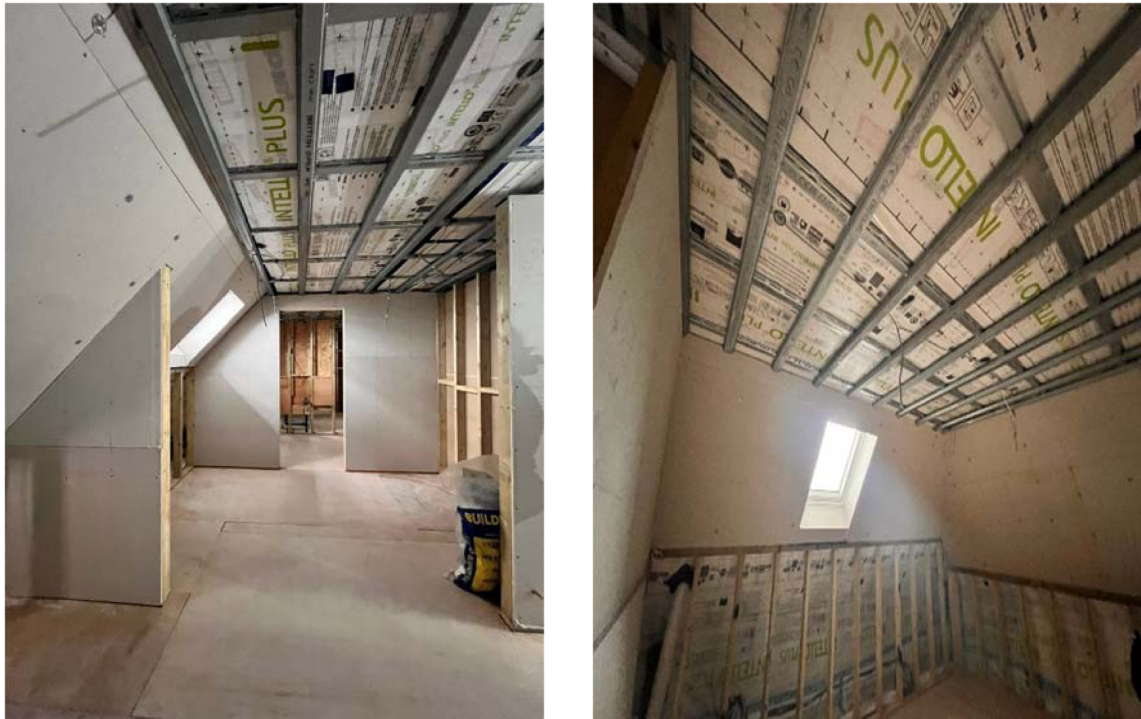


Fig. 7. Layered construction of pitched roof showing timber structure and insulation detailing—crucial for thermal performance and compliance with UK Building Regulations Part L.41 Seymour Road.



Fig. 8. External façade of Bathgate Road featuring clay brickwork and high-spec insulated cavity construction.

concepts of climate appropriate and sustainable housing design.

The Kunst Museum in Switzerland is an innovative institutional response to the architectural needs of the cold climate, through high levels of envelope engi-

neering and environmental control [50]. The façade system is designed to achieve high performance in both the insulating materials used and in the airtight construction methods, which results in the infiltration heat losses being significantly minimized and thus

the total energy efficiency is enhanced. The design is an envelope that admits daylight in a controlled manner, while keeping thermal bridging to a minimum, and uses strategically placed systems of glazing to achieve a high level of diffuse natural daylight with minimal thermal bridging [23]. The building features high-performance curtain wall or insulated façade assemblies to help control the internal microclimates that are essential for the comfort of the building's occupants as well as for the preservation of the artworks. It is ensured by the choice of materials and façade articulation, so as to reduce passive solar gain and maintain stable interior temperatures regardless of seasonal changes. Also, mechanical loads are reduced via envelope efficiency by reducing active heating loads [23]. The architectural solution not only embodies a systems-based integration of material science, environmental engineering and passive climate responsiveness, but also serves as a blue-print for sustainable cultural infrastructure in cold regions.

The Kunst Museum in Switzerland was a key step in adapting to the existing climate through another approach. The selection of materials for insulation and energy efficiency was very important. The façade of the Kunst Museum is like that of the Bianchi House; it was designed to allow daylight while at the same time helping to retain heat. The building achieves a sustainable thermal environment with the help of advanced insulation techniques and airtight construction methods, thus reducing the requirement for excessive artificial heating.

The different architectural responses to these climatic conditions are these examples. By capitalizing on the environmental constraints through material selection, spatial organization and passive design techniques, architects can develop environmentally responsive and sustainable buildings in the long term [22].

2. Methodology

2.1. Research design

In this study, a qualitative comparative case study method was used to explore different passive design strategies, integration of sustainability, procurement, the coordination of stakeholders, and compliance with regulations in residential architectural projects under varying climate conditions. It was decided to adopt a comparative case study approach as this enabled to systematically analyse the architectural approach, environmental strategies and project delivery processes within the actual built context. The study concentrates on the identification of climate, technical and regulatory requirements and passive

environmental design measures in relation to each other in residential projects.

2.2. Case study selection

This study utilized a combination of historical case studies and personal architectural projects in the UK context and internationally to explore passive strategies in climate-responsive domestic architecture. Case studies were purposefully selected because they were relevant to the research's objectives. Projects were selected based on the use of a passive environmental design approach, the focus on sustainability, and the unique climatic or regulatory conditions. Bathgate Road and Seymour Road were chosen as the key UK-based case studies as they demonstrated contrasting methods of residential procurement, how sustainability was integrated, how the various stakeholders worked together and the planning compliance requirements.

The international case studies have not been considered in terms of direct comparison with UK residential buildings in terms of performance, but rather have been included as an indication of how different climates can be accommodated using passive architectural design techniques. Other examples in different climatic contexts were added to enhance the geographical comparability between different practices of climate-responsive passive design in different climate conditions.

2.3. Data sources and collection

The secondary and project based documentary sources were used in the study. Data obtained from architectural drawings, planning applications, procurement records, technical specification documents, sustainability reports, conservation guidance documents, building regulations and peer-reviewed literature. Further information was collected from public documents, like regulatory and planning documents linked to the selected projects. The gathered materials were analysed and categorized in order to facilitate systematic comparative analysis on environmental, technical, management and procurement-related themes.

2.4. Comparative analysis framework

Thematic comparative evaluation framework was used for the analysis. The projects were evaluated based on the passive design measures adopted, the thermal comfort, natural ventilation, daylighting, materials, insulation, procurement process, coordination among stakeholders, sustainability goals and

compliance with regulatory requirements. Case study analysis was performed first in each individual case study to develop project specific strategies and challenges, and then cross case comparison was performed to identify the common themes, similarities and the contextual differences among the project cases.

2.5. Analytical procedure

Analytical work involved the review of project document and literature to identify major themes in architectural, environmental, procurement and sustainability. The identified themes were categorized and compared to assess the contribution of passive design strategies and procurement decisions toward sustainable goals and residential building performance in different climates and regulations.

2.6. Scope and limitations

This is a qualitative study and there is no post-occupancy quantitative data (such as thermal simulations, EPC ratings, SAP calculations or operational energy monitoring data). In conclusion, the results should be considered as a comparative study of the implementation of passive design from an architectural and procurement perspective and not as a building performance study.

3. Results and discussion

3.1. Passive strategies in domestic architecture

In domestic architecture within this field, energy efficiency is optimized to ensure indoor comfort. Some of these principles are solar orientation [16], thermal mass [26], shading devices and cross ventilation [29], which are some of the best methods to reduce energy consumption and increase environmental performance.

3.2. Solar orientation & thermal mass

The orientation of buildings should be in such a way as to take advantage of winter sunlight and avoid overheating in summer [44]. South-facing windows at Bathgate Road provide the best winter solar gain, with shading devices that shield the windows from excessive summer heat. Seymour Road shares common features with other housing estates in southeast England, whereby bricks are used for walls that help provide thermal mass. Brick walls absorb heat energy during the day, then release the absorbed heat during the night.

3.3. Shading devices

Overhangs, brise soleil and recessed windows serve to shade and prevent overheating, enhancing thermal comfort [51]. Luis Barragán possesses a stunning understanding of how enclosed, well-lit spaces are effective, unlike the deep window recesses in the Fisher House.

As emphasized by Hasman [8], effective use of shading devices and cross-ventilation is key to reducing reliance on mechanical cooling systems, a strategy demonstrated in Seymour Road. At Kunst Museum, overhanging roofs and deep-set windows take sunlight effectively out of course, as does Bathgate Road with fixed louvres for reducing glare and too much solar heat gain. Fig. 9 illustrates the roof construction and roof-window arrangement incorporated into the Seymour Road project, to take sunlight effectively, natural ventilation and thermal performance.

3.4. Cross-ventilation

Another important passive approach used for natural air flow is cross ventilation which helps in reducing the use of mechanical cooling systems [29]. At Seymour Road, large bi-fold openings serve to allow continuous movement of comfortable indoor air without the aid of artificial coolers. Just as Casa de Vidro can improve passive ventilation with its elevating, the structure can do the same here.

Together, these passive strategies demonstrate how a person can design domestic architecture in harmony with the environment. Solar orientation can be optimized, shading devices can be incorporated, thermal mass can be used and wind cross ventilation can be encouraged [33, 52] to make homes more livable and sustainable for architects.

3.5. Material & construction strategies for sustainability

3.5.1. Sustainable materials

Energy efficiency and environmental performance of buildings is a crucial part in the build-up to sustainable materials selection [13, 14]. In particular, timber, brick and stone are used for their durability, insulating properties and ability to regulate indoors temperatures effectively. These materials minimize the use of synthetic insulation and high energy construction processes to help build a carbon footprint that seem reduced [3, 12]. Moreover, they also provide the benefit of long-term sustainability like low maintenances, resilience in structural properties.

Seymour Road made use of high-performance brick and timber cladding in order to ensure a thermally

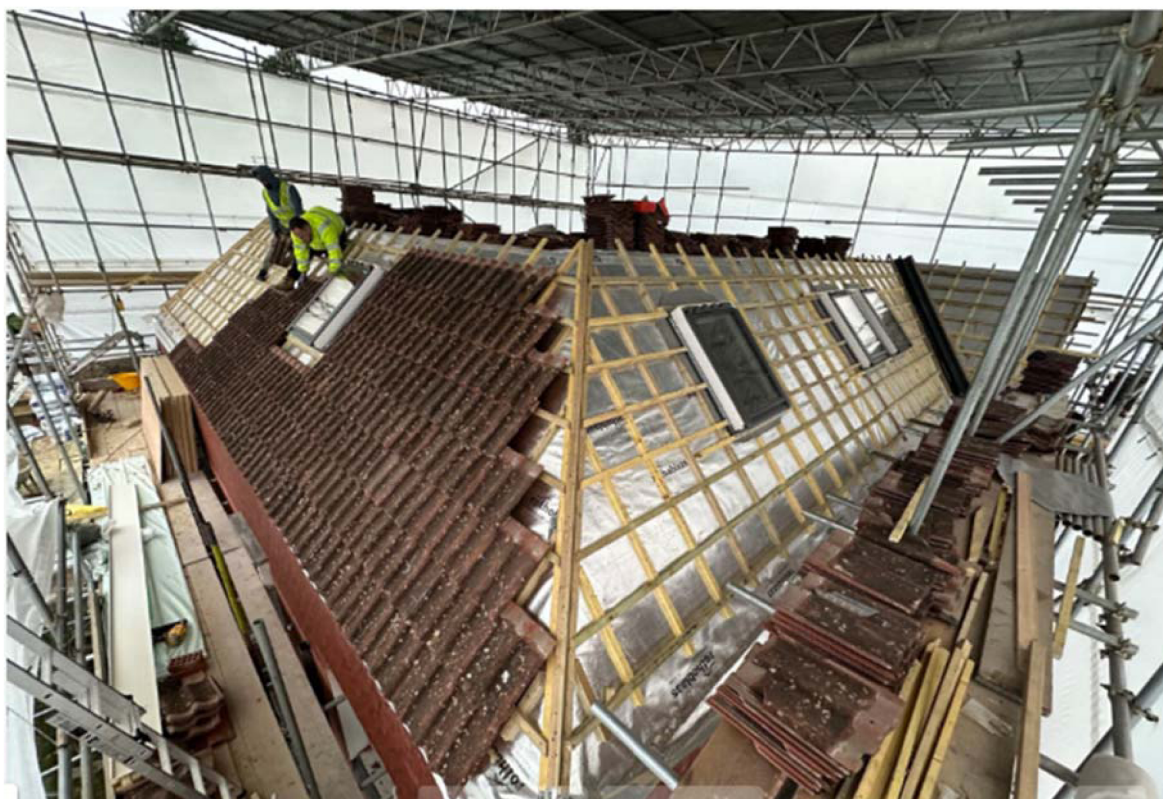


Fig. 9. Wimbledon Loft Conversion-Roof.

efficient building envelope. By extensively discussing sustainable material choices such as timber, brick and stone, Hasman [8] also makes an important contribution to achieving thermal comfort in domestic architecture, reducing environmental impact, as well as achieving longevity by using strategies that have worked in architectural history of the past to address the technological challenges of climate design. In addition, these materials facilitate sustainable building techniques that utilize local and renewable resources, and, as such, this promotes energy efficiency [5]. Brick has good thermal mass, that is it stores and then releases heat, hence keeping the inside temperature from fluctuating. However, one of the best utilities of timber is that it acts as a natural insulator, keeping heat inside and out of the house while still allowing for a breathable indoor environment [53].

Bathgate Road also reused stone cladding to construct the building through its sustainable construction strategy. In order to introduce thermal improvements, stone, a highly durable and energy-efficient material, was integrated, complimenting the building's architectural aesthetics. Stone has its natural thermal mass and can absorb the heat during the day and release it at night, reducing the need for artificial heating [54]. In addition, its longevity allows

the building to be resilient over time and thus reduce its environmental impacts of material replacement, maintenance, etc.

Fig. 10 demonstrates a commitment to airtight construction and thermal performance, aligning with the UK Future Homes Standard. On-site application of mineral wool insulation in timber-frame walls, as seen in Fig. 10, enhances thermal resistance and airtightness. This approach directly supports low-carbon housing strategies and improves occupant comfort.

Optimizing energy efficiency in buildings requires tight insulation and air tightness. These strategies allow the indoor temperatures to be reduced, which means the energy used to heat and cool is reduced. Insulation also prevents drafts and maintains temperature levels that promote occupant comfort [33].

The airtightness measures at Kunst Museum were further advanced to reduce energy loss and achieve a better overall thermal performance. The museum chose high-performance insulation systems with precise sealing techniques and great air tightness (air leakage), limiting it to a controlled indoor climate. As a result of this approach, heating demands were reduced, and the overall sustainability of the building was improved because it reduced the dependence on the building being mechanically climate-controlled



Fig. 10. Timber frame construction showing mineral wool insulation during on-site installation at Wimbledon loft conversion.

[55]. These airtightness measures are integrated to show how strategic construction techniques can make a resourceful contribution to long-term energy savings [56].

These images in Fig. 11, reflect the real-time delivery of a low-energy strategy—integrating thermal and acoustic insulation, controlled envelope layering, and precise construction sequencing, aligned with Future Homes Standard targets for airtightness and energy performance. The on-site build-up of Seymour Road reinforces the strategic alignment between design intent and execution. As illustrated in Fig. 11, the project employed multiple insulation layers, membrane detailing, and airtight envelope techniques to minimise thermal bridging and maximise envelope performance. Carefully coordinated installations—such as the Velux rooflights and staircase structures—were executed with thermal continuity in mind. These layers not only address environmental performance but also improve acoustic comfort and reduce operational energy use in line with Part L and the Future Homes Standard.

In the same way, Bathgate Road used high-insulation materials to increase heat retention and enhance thermal comfort. Adding insulation of a high R-value reduced the heat transfer, thus minimizing the requirement for high heating in the winter months [52]. A further careful selection of airtight

construction materials was selected to guarantee that conditioned air remained inside; thus, no energy was lost, and indoor air quality was optimized [44]. The insulating and airtight elements of these built forms demonstrate the importance of how insulation and airtightness are key elements of sustainable architecture that contribute to both environmental and economic efficiency [27].

3.5.2. Comparative analysis of passive strategies

Passive strategies are integrated in UK projects, Bathgate Road and Seymour Road, under the limitations of UK Building Regulations, Part L – Conservation of Fuel and Power and the Future Homes Standard. These regulatory frameworks set very strict energy efficiency targets, airtightness requirements and carbon emission reductions but these are taken into account when architects designing to ARB GC2 for environmental sustainability take into account climate responsive design [57, 58]. Regulatory constraint in UK building differs from international case study, where regulatory constraints are less restrictive but the UK buildings need to balance their sustainability goals with regulatory constraints [59]. Casa de Vidro for instance in Brazil, uses raised structures to maximise natural airflow; UK projects however have to be the most efficient in insulation, airtight detailing, and controlled ventilation in order to comply with regulations.

In comparison, UK and international case studies are used to demonstrate how regional building policies guide climate adaptive strategies. The passive cooling strategies such as open courtyards, shading devices, and wind towers are not commonly used in UK architecture as they involve international projects experimenting with these strategies given the strict controls for insulation and moisture control [60]. On the other hand, UK developments typically include airtight construction, high performance insulation, and mechanical ventilation systems to minimize heat loss and increase energy performance [57].

In addition, UK projects also need to have regulated U values, Standard Assessment Procedure (SAP) calculations, and future 2025 homes standard, indicating that design principles not only meet sustainability objectives but also invite longer building life time and better occupant comfort [61, 62]. Analysing these various approaches will help architects to develop best practices by which regulatory compliance and climate responsive strategies can equally serve as drivers for both energy efficiency and occupant well-being in sustainable design solutions.

Here is a comparative table summarizing the passive strategies used in UK projects versus international case studies:

Table 1. Comparative analysis of passive design strategies in UK projects and international case studies.

Passive Strategy	UK Projects	International Case Studies
Solar Orientation	Optimized for seasonal changes with south-facing windows and shading in summer (Bathgate Road).	Maximized solar gain due to arid/tropical settings, using large openings and natural light control (Kaufmann House, Casa de Vidro).
Shading Devices	Overhangs and recessed windows reduce heat and glare (Seymour Road).	Brise soleil and deep-set glazing regulate solar heat (Luis Barragán, Fisher House).
Ventilation	Bifold openings and cross-ventilation enhance airflow and minimize reliance on mechanical cooling (Seymour Road).	Open courtyards, raised structures, and stack ventilation methods encourage airflow in hot climates (Santillana Beach House).
Thermal Mass	Brick and stone provide insulation and temperature stability throughout the year (Bathgate Road).	Mud-brick and concrete absorb heat during the day and release it at night, improving thermal regulation (Akil Sami House).

3.6. Discussion

From the results, the adaptation of passive design strategies to regional climatic conditions, regulatory constraints, and material availability are analyzed. Differences are found in architectural approaches, material choices, the use of passive methods, and other aspects [52] in UK and international projects.

They have to do with architectural control in disparate climates. Bathgate Road and Seymour Road are UK projects which is integrating passive strategy into the existing building regulations scope regarding the lesson energy efficiency and survival standards. In turn, international examples like Santillana Beach House and the Kaufmann House do not need to employ such radical ways of doing things as a way of designing as a system for the passive approach. These projects use all available means of unrestricted architectural forms e.g. open courtyard and raised forms to the next optimum extensions to achieve optimum ventilation and shading [33]. The same flexibility in design is revealed also in the application of international case studies and demonstrates the possibility of applying innovative passive strategies under less restrictive regulatory constraints.

The other key factor affecting passive design is materiality. Material selection in UK projects is oriented towards balancing insulation as much as heat retention [20]. High-performance brick, timber, and stone provide durability and thermal efficiency on Bathgate Road and Seymour Road. Nevertheless, much stricter insulation and airtightness are necessary outside the project boundaries due to the energy efficiency demands of colder climates, such as those in international projects like the Kunst Museum in Switzerland. A similar process occurs in Egypt in arid regions where traditional mud brick construction is done to harness its inherent thermal massing properties in order to minimize mechanical cooling. The comparison of these material choices proposes that climate-responsive design cannot solely factor in the local regional aspects but must also take into account the real case construction.

UK housing could integrate passive cooling techniques from hot climates, such as wind towers for ventilation and courtyards for heat reduction (Santillana Beach House). Applying these strategies would enhance energy efficiency and occupant comfort while reducing environmental impact. Passive design strategies vary by climate and regulatory framework, but the principles of climate-responsive

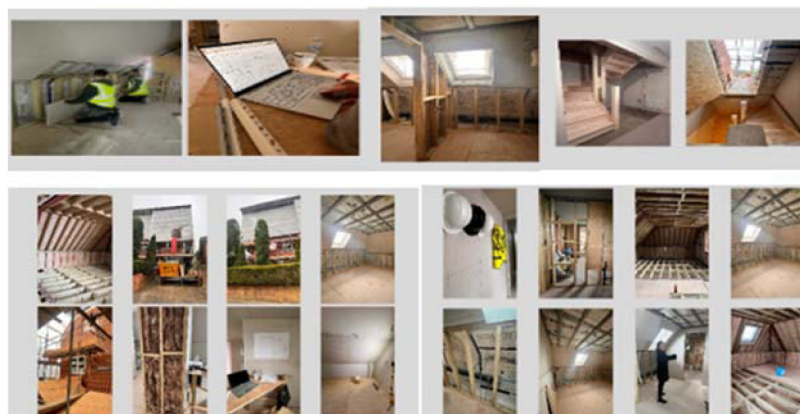


Fig. 11. On-site construction sequence from Seymour Road project, showing insulation installation, airtight membrane detailing, Velux openings, and stair integration.



Fig. 12. Completed interior spaces in Bathgate Road project reflecting the thermal and acoustic comfort achieved through airtight construction and passive design principles.

architecture are universal. Achieving this dependence on the continued evolution of sustainable design on integrating lessons from diverse environmental contexts to build resilient, energy-efficient buildings lies within the hands of architects [32].

While this study does not include post-occupancy energy monitoring data, several quantitative indicators demonstrate the effectiveness of the adopted passive strategies. At Bathgate Road, 100 mm PIR cavity wall insulation (thermal conductivity is 0.022 W/m·K) and insulated glazing (U-value equals 1.6 W/m²K) were installed to minimize heat loss and increase thermal performance of the building. In addition, the project uses details and techniques of the air-tight envelope and moisture protection aimed at compliance with the requirements of the Building Regulation Part L. The use of solar PV array of the capacity of 4.3 kWp, battery storage, insulation materials, and MVHR was implemented in the construction of the house in Seymour Road. Despite inability to identify exact savings in energy due to the qualitative nature of the analysis, it can be concluded that the measures applied have positive influence on the energy performance of the building.

Furthermore, through its climate-driven approach architecture develops strong resistance to future challenges. City settings like UK homes experience extreme summer temperatures near 40 °C nowadays; so architects need to use shading elements and airflow tools to keep buildings from overheating [51, 63]. This research adds to urban development discussions by showing architects the most effective way to build passive solutions for climate challenges that buildings may face in future.

4. Conclusion

Climate-responsive design serves as a research tool for domestic architecture to integrate passive strategies that improve building sustainability and reduce energy use while meeting residents' needs. The ap-

plication of passive building design needed to follow local conditions especially the national rules about materials and climate. With the adoption of provided strategies, UK architecture has the potential to continue to reduce the energy use and occupant comfort impacts of built structures and minimise the environmental impact of the built structures. With these reflections, we highlight that while the passive design strategies can be different through different climate conditions and regulatory frameworks, the principles of climate-responsive architecture are universally relevant. Architects must learn from different contexts and gather lessons to create energy-efficient resilient buildings that will continue to evolve for sustainable design.

4.1. Implications

Comparison of the UK projects has provided insights to balance sustainability objectives with regulatory compliance, and the analysis of international case studies has helped to provide valuable insights into adaptive design approaches. The findings from this study provide environmentally responsible architectural solutions, meeting the UK policy frameworks by using global best practices. This study indicated that passive cooling can also be facilitated through open courtyards, as in the Santillana Beach House, which can be integrated into residential designs similar to how they are designed today. This study will also help to improve the understanding of technical aspects related to climate-responsive materials and energy efficiency strategies. By going through case studies and transferring lessons from international examples, we have built up the strength to incorporate passive design principles in future architecture projects.

4.2. Future recommendations

Applying passive techniques to UK housing could enhance energy efficiency and occupant comfort,

incorporating strategies such as wind towers, open courtyards, and optimized ventilation methods inspired by international case studies.

Conflict of interest

The author declares no conflict of interest.

Author contribution

Data availability

All data is present in the Manuscript.

Funding

None.

References

- Perdue JL. Architects, climate change, and resilience: Bridging gaps between research and practice: royal roads University (Canada); 2024. <https://www.proquest.com/openview/a3fa308837df297cec998cb61d60c3b8/1?pq-origsite=gscholar&cbl=18750&diss=y>.
- Faircloth B, Zari MP, Thomsen MR, Tamke M. Design for Climate Adaptation: Proceedings of the UIA World Congress of Architects Copenhagen 2023: Springer Nature; 2024. https://books.google.com.pk/books?hl=en&lr=&id=x7frEAAQBAJ&oi=fnd&pg=PR5&dq=Faircloth+B,+Zari+MP,+Thomsen+MR,+Tamke+M.+Design+for+Climate+Adaptation:+Proceedings+of+the+UIA+World+Congress+of+Architects+Copenhagen+2023:+Springer+Nature%3B+2024.&ots=Gr32v2PuWc&sig=bQ5URq3Gb8HZKdy1XiJTsj7n-PA&redir_esc=y#v=onepage&q&f=false.
- Mba EJ, Okeke FO, Igwe AE, Ozigbo CA, Oforji PI, Ozigbo IW. Evolving trends and challenges in sustainable architectural design; a practice perspective. *Heliyon*. 2024. <https://doi.org/10.1016/j.heliyon.2024.e39400>.
- Bitik D. Climate-responsive HBIM for sustainable preservation: a case study of Villa Ottolini Tovaglieri-environmental impact and preservation strategies. 2023. <https://www.politesi.polimi.it/handle/10589/223026>.
- Zhang M, Yan T, Wang W, Jia X, Wang J, Klemeš JJ. Energy-saving design and control strategy towards modern sustainable greenhouse: A review. *Renewable and Sustainable Energy Reviews*. 2022;164:112602. <https://doi.org/10.1016/j.rser.2022.112602>.
- Adua L, Asamoah A, Barrows J, Brookstein P, Chen B, Coleman DR, et al. Ambient energy for buildings: Beyond energy efficiency. *Solar Compass*. 2024;11:100076. <https://doi.org/10.1016/j.solcom.2024.100076>.
- Lucchi E, Turati F, Colombo B, Schito E. Climate-responsive design practices: A transdisciplinary methodology for achieving sustainable development goals in cultural and natural heritage. *Journal of Cleaner Production*. 2024;457:142431. <https://doi.org/10.1016/j.jclepro.2024.142431>.
- Hasman M. RIBA Climate Guide: RIBA Publishing; 2023. DOI: 10.4324/9781003382485.
- Al-Ghaili AM, Ibrahim Z-AB, Bakar AA, Kasim H, Al-Hada NM, Jørgensen BN, et al. A systematic review on demand response role toward sustainable energy in the smart grids-adopted buildings sector. *IEEE Access*. 2023;11:64968–5027. <https://doi.org/10.1109/ACCESS.2023.3287641>.
- Sudarsan A, Chithra K. The role of energy management in transition towards green cities: A review. *Environment, Development and Sustainability*. 2024;1–23. <https://doi.org/10.1007/s10668-024-04830-z>.
- Tabb PJ. Biophilic urbanism: Designing resilient communities for the future: Routledge; 2020. <https://lcn.loc.gov/>.
- Ramezani H, Reza E. The consequence of combining indigenous techniques with a flexible design to reduce energy consumption in residential buildings for future architecture. *Sustainability*. 2022;14(21):13958. <https://doi.org/10.3390/su142113958>.
- Hong C, Yang Y, Ge S, Chai G, Zhao P, Shui Q, et al. Is the design guidance of color and material for urban buildings a good choice in terms of thermal performance? *Sustainable Cities and Society*. 2022;83:103927. <https://doi.org/10.1016/j.scs.2022.103927>.
- Almusaed A, Almssad A, Homod RZ, Yitmen I. Environmental profile on building material passports for hot climates. *Sustainability*. 2020;12(9):3720. <https://doi.org/10.3390/su12093720>.
- Papadakis N, Katsaprakakis DA. A review of energy efficiency interventions in public buildings. *Energies*. 2023;16(17):6329. <https://doi.org/10.3390/en16176329>.
- Salem E, Elwakil E. Innovative methods to optimize the integration of passive solar design principles into buildings. *Innovative Infrastructure Solutions*. 2024;9(9):339. <https://doi.org/10.1007/s41062-024-01635-x>.
- Zhang W, Wu Y, Calautit JK. A review on occupancy prediction through machine learning for enhancing energy efficiency, air quality and thermal comfort in the built environment. *Renewable and Sustainable Energy Reviews*. 2022;167:112704. <https://doi.org/10.1016/j.rser.2022.112704>.
- Belmonte M-V, Díaz-López C, Gavilanes J, Millán E. Introducing passive strategies in the initial stage of the design to reduce the energy demand in single-family dwellings. *Building and Environment*. 2021;197:107832. <https://doi.org/10.1016/j.rser.2022.112704>.
- Yalaz E, Dişli G. Climate-responsive building façade design: Inspirations from historic buildings in semi-cold climate zone. *Sustainable Energy Technologies and Assessments*. 2024;69:103914. <https://doi.org/10.1016/j.rser.2022.112704>.
- Kalu Arachchi K, Perera B, Raigama Acharige DP, Jayasuriya S. A framework for sustainable tropical design: converging circular economy into passive design strategies. *Construction Innovation*. 2025. <https://doi.org/10.1108/CI-06-2024-0166>.
- Hassani EK. Preserving the past, designing the future: unveiling climate-resilient design in persian vernacular architecture for modern sustainability. *Persian Vernacular Architecture: Lessons from Master Builders of Iran on Climate Resilient Design*: Springer; 2025. p. 277–303. https://doi.org/10.1007/978-981-96-1116-4_15.
- Fragalla AM, Asadi S. Biomimetic design for adaptive building façades: a paradigm shift towards environmentally conscious architecture. *Energies*. 2022;15(15):5390. <https://doi.org/10.1108/CI-06-2024-0166>.
- Cheibas I, Lloret-Fritschi E, Rachele C, Delbeke M, Rust R, Gra-mazio F, et al., editors. Emerging building technologies and their impact on facade design. Construction Matters: Proceedings of the 8th International Congress on Construction History;

- VDF Hochschulverlag AG: Zolicon, Switzerland; 2025. <https://books.google.co.uk/books?id=phRMEQAAQBAJ&lpg=PA371&ots=Acc5stJBH&dq=Cheibas%20I%2C%20Lloret-Fritsch%20E%2C%20Rachele%20C%2C%20Delbeke%20M%2C%20Rust%20R%2C%20Gramazio%20F%2C%20et%20al.%2C%20editors.%20Emerging%20building%20technologies%20and%20their%20impact%20on%20facade%20design.%20Construction%20Matters%3A%20Proceedings%20of%20the%208th%20International%20Congress%20on%20Construction%20History%3B%20VDF%20Hochschulverlag%20AG%3A%20Zolicon%2C%20Switzerland%3B%202025.&lr&pg=PP1#v=onepage&q&f=false>.
24. Ali G, Robert W, Hassan H. The role of passive techniques in modern sustainable architecture. *KHWARIZMIA*. 2024;2024:105–17. <https://doi.org/10.70470/KHWARIZMIA/2024/014>.
 25. Toroxel JL, Silva SM. A review of passive solar heating and cooling technologies based on bioclimatic and vernacular architecture. *Energies*. 2024;17(5):1006. <https://doi.org/10.3390/en17051006>.
 26. Yang L, Fu R, He W, He Q, Liu Y. Adaptive thermal comfort and climate responsive building design strategies in dry-hot and dry-cold areas: Case study in Turpan, China. *Energy and Buildings*. 2020;209:109678. <https://doi.org/10.1016/j.enbuild.2019.109678>.
 27. Kaasalainen T, Mäkinen A, Lehtinen T, Moisio M, Vinha J. Architectural window design and energy efficiency: Impacts on heating, cooling and lighting needs in Finnish climates. *Journal of Building Engineering*. 2020;27:100996. <https://doi.org/10.1016/j.jobe.2019.100996>.
 28. Elaouzy Y, El Fadar A. Impact of key bioclimatic design strategies on buildings' performance in dominant climates worldwide. *Energy for Sustainable Development*. 2022;68:532–49. <https://doi.org/10.1016/j.esd.2022.05.006>.
 29. Ali RA, Megahed NA, Shahda MM, Hassan AM. Natural ventilation as a passive cooling strategy for multi-story buildings: analytic vertical sky court formations. *City, Territory and Architecture*. 2023;10(1):28. <https://doi.org/10.1186/s40410-023-00212-6>.
 30. Soussi M, Chaibi MT, Buchholz M, Saghrouni Z. Comprehensive review on climate control and cooling systems in greenhouses under hot and arid conditions. *Agronomy*. 2022;12(3):626. <https://doi.org/10.3390/agronomy12030626>.
 31. Halawa E, Bruno F. Energy performance and thermal comfort delivery capabilities of solid-desiccant rotor-based air-conditioning for warm to hot and humid climates—A critical review. *Energies*. 2023;16(16):6032. <https://doi.org/10.3390/en16166032>.
 32. Sholanke A, Ganya Z. Review of passive design strategies for sustainable development: A focus on energy efficient strategies for tropical climates. *Covenant Journal of Research in the Built Environment*. 2024. <https://journals.covenantuniversity.edu.ng/index.php/cjrbe/article/view/4838/1742>
 33. Arumugam P, Ramalingam V, Vellaichamy P. Effective PCM, insulation, natural and/or night ventilation techniques to enhance the thermal performance of buildings located in various climates—A review. *Energy and Buildings*. 2022;258:111840. <https://doi.org/10.1016/j.enbuild.2022.111840>.
 34. Palarino C, Piderit MB. Optimisation of passive solar design strategies in side-lit offices: Maximising daylight penetration while reducing the risk of glare in different Chilean climate contexts. *Journal of Daylighting*. 2020;7(1):107–21. <http://dx.doi.org/10.15627/jd.2020.9>.
 35. Carrobé A, Rincón L, Martorell I. Thermal monitoring and simulation of earthen buildings. A review. *Energies*. 2021;14(8):2080. <https://doi.org/10.3390/en14082080>.
 36. Kaitouni SI, Charai M, Es-Sakali N, Mghazli MO, El Mankibi M, Uk-Joo S, et al. Energy and hygrothermal performance investigation and enhancement of rammed earth buildings in hot climates: from material to field measurements. *Energy and Buildings*. 2024;315:114325. <https://doi.org/10.1016/j.enbuild.2024.114325>.
 37. Suhane S. To analyze the application of passive design techniques for Residential high-rise building. 2023. <https://shorturl.at/mAbmW>.
 38. Matos AM, Delgado JM, Guimarães AS. Energy-efficiency passive strategies for mediterranean climate: an overview. *Energies*. 2022;15(7):2572. <https://doi.org/10.3390/en15072572>.
 39. Gonçalves M, Figueiredo A, Almeida R, Vicente R. Dynamic façades in buildings: A systematic review across thermal comfort, energy efficiency and daylight performance. *Renewable and Sustainable Energy Reviews*. 2024;199:114474. <https://doi.org/10.1016/j.rser.2024.114474>.
 40. Attia S, Bertrand S, Cuchet M, Yang S, Tabadkani A. Comparison of thermal energy saving potential and overheating risk of four adaptive façade technologies in office buildings. *Sustainability*. 2022;14(10):6106. <https://doi.org/10.3390/su14106106>.
 41. Pajek L, Košir M. Strategy for achieving long-term energy efficiency of European single-family buildings through passive climate adaptation. *Applied Energy*. 2021;297:117116. <https://doi.org/10.1016/j.apenergy.2021.117116>.
 42. Sun H. Multidimensional analysis of courtyard building environmental performance using computational fluid dynamics: University of Nottingham; 2024. <https://shorturl.at/V6r3l>.
 43. Fleck R, Gill R, Pettit T, Torpy F, Irga P. Bio-solar green roofs increase solar energy output: The sunny side of integrating sustainable technologies. *Building and Environment*. 2022;226:109703. <https://doi.org/10.1016/j.buildenv.2022.109703>.
 44. Ali BM, Akkas M. The green cooling factor: Eco-innovative heating, ventilation, and air conditioning solutions in building design. *Applied Sciences*. 2023;14(1):195. <https://doi.org/10.3390/app14010195>.
 45. Zheng W, Wei F, Su S, Cai J, Wei J, Hu R. Effect of the envelope structure on the indoor thermal environment of low-energy residential building in humid subtropical climate: In case of brick-timber vernacular dwelling in China. *Environmental Technology & Innovation*. 2022;28:102884. <https://doi.org/10.1016/j.eti.2022.102884>.
 46. Pásztor Z. An overview of factors influencing thermal conductivity of building insulation materials. *Journal of Building Engineering*. 2021;44:102604. <https://doi.org/10.1016/j.jobe.2021.102604>.
 47. Alvur E, Cuce PM, Cuce E, Bouabidi A, Soudagar MEM. Thermal bridging in windows: A critical review on mitigation strategies for enhanced building energy efficiency. *Sustainable and Clean Buildings*. 2024:176–93. <https://shorturl.at/jUGEO>
 48. Machura R. Between form and history: the houses of Mario Botta as an expression of the idea of continuity in architecture. DOI: 10.23817/2025.defarch.5-8.
 49. Zheng Y, Lin Y, Zhao L, Wu T, Jin D, Li Y. Spatial planning of urban communities via deep reinforcement learning. *Nature Computational Science*. 2023;3(9):748–62. <https://doi.org/10.5281/zenodo.8175420/> or <https://www.nature.com/articles/s43588-023-00503-5>.
 50. Sachs A. Context Analysis. Luise Reitstätter, Carla-Marinka Schorr (eds). 2025:75. <https://shorturl.at/OJDAq>

51. Albatayneh A, Albadaïneh R, Juaidi A, Abdallah R, Zabalo A, Manzano-Agugliaro F. Enhancing the energy efficiency of buildings by shading with PV panels in semi-arid climate zone. *Sustainability*. 2022;14(24):17040. <https://doi.org/10.3390/su142417040>.
52. Yao X, Dewancker BJ, Guo Y, Han S, Xu J. Study on passive ventilation and cooling strategies for cold lanes and courtyard houses—A case study of rural traditional village in Shaanxi, China. *Sustainability*. 2020;12(20):8687. <https://doi.org/10.3390/su12208687>.
53. Klemczak B, Kucharczyk-Brus B, Sulimowska A, Radziejewicz-Winnicki R. Historical evolution and current developments in building thermal insulation materials—A review. *Energies*. 2024;17(22):5535. <https://doi.org/10.3390/en17225535>.
54. Kim YU, Yun BY, Nam J, Choi JY, Wi S, Kim S. Evaluation of thermal properties of phase change material-integrated artificial stone according to biochar loading content. *Construction and Building Materials*. 2021;305:124682. <https://doi.org/10.1016/j.conbuildmat.2021.124682>
55. Rahif R. *Impact of Climate Change on High-Performance Belgian Houses: Thermal Comfort, HVAC Energy Performance, and HVAC GHG Emissions*: Universite de Liege (Belgium); 2023. <https://shorturl.at/CytnO>
56. Elaouzy Y, El Fadar A. Energy, economic and environmental benefits of integrating passive design strategies into buildings: A review. *Renewable and sustainable energy reviews*. 2022;167:112828. <https://doi.org/10.1016/j.rser.2022.112828>.
57. Vagtholm R, Matteo A, Vand B, Tupenaite L. Evolution and current state of building materials, construction methods, and building regulations in the UK: Implications for sustainable building practices. *Buildings*. 2023;13(6):1480. <https://doi.org/10.3390/buildings13061480>.
58. Harris C. Opaque envelopes: Pathway to building energy efficiency and demand flexibility: Key to a low-carbon, sustainable future. National Renewable Energy Lab.(NREL), Golden, CO (United States); 2021. <https://doi.org/10.2172/1821413>
59. Stopps H, Thorncroft C, Touchie MF, Zimmermann N, Hamilton I, Kesik T. High-rise residential building makeovers: Improving renovation quality in the United Kingdom and Canada through systemic analysis. *Energy Research & Social Science*. 2021;77:102085. <https://doi.org/10.1016/j.erss.2021.102085>.
60. Adeyina DL. Exploring the passive house framework in cooling-dominated climates: Auckland University of Technology; 2022. <http://hdl.handle.net/10292/16561>
61. Schumm M. *The Real Estate Sector's Reflection on Sustainability in the Real Estate Sector*: University of Wales Trinity Saint David (United Kingdom); 2024. <https://shorturl.at/ap7P1>
62. Oreskovic L. *Evaluating the real energy and environmental performance of an eco-housing development in England*: Oxford Brookes University; 2022. <https://shorturl.at/6HmGr>
63. Valitabar M, Mahdavienejad M, Skates H, Pilechiha P. A dynamic vertical shading optimisation to improve view, visual comfort and operational energy. *Open House International*. 2021;46(3):401–15. <https://doi.org/10.1108/OHI-02-2021-0031>.