Weeranayaka, P.A.D.D.J., Bandara, R.M.H.R. and Thayaparan, M., 2026. Learning from nature: Biomimicry-inspired daylighting design for reducing artificial lighting in urban buildings. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Chandanie, H. and Tennakoon, G.A. (eds). *Proceedings of the 14th World Construction Symposium*, 10-11 July 2026, Sri Lanka. pp. 1065-1078. DOI: https://doi.org/10.31705/WCS.2026.78. Available from: https://ciobwcs.com/papers/

LEARNING FROM NATURE: BIOMIMICRY-INSPIRED DAYLIGHTING DESIGN FOR REDUCING ARTIFICIAL LIGHTING IN URBAN BUILDINGS

P.A.D.D.J. Weeranayaka[1], R.M.H.R Bandara[2], and M. Thayaparan[3]

ABSTRACT

Urban buildings are major contributors to global energy consumption, with artificial lighting representing a significant share of operational electricity demand, particularly in dense urban environments with limited daylight access. Improving natural daylight utilisation has therefore become an important strategy for enhancing building energy efficiency and reducing environmental impacts. Biomimicry, which involves learning from natural forms and processes to solve human design challenges, offers promising opportunities for developing innovative daylighting strategies in architecture. This study evaluates the effectiveness of biomimicry-inspired daylighting strategies in reducing artificial lighting demand in urban buildings. A comparative multiple case study approach was adopted, examining five international buildings incorporating nature-inspired façade systems: Institut du Monde Arabe (France), Sinosteel International Plaza (China), Habitat 2020 (China), Esplanade – Theatres on the Bay (Singapore), and Al Bahar Towers (UAE). Data were collected from architectural documentation, published studies, and reported daylighting performance indicators. The analysis identified key biomimetic daylighting strategies, including adaptive kinetic façades, parametric shading systems, responsive building skins, and geometric façade patterns. Findings indicate that these strategies improve daylight distribution and reduce artificial lighting demand by approximately 20–80%, depending on climatic context and façade configuration. As an exploratory secondary-data-based comparative study, the findings provide an initial foundation for understanding how biomimicry-inspired façade systems contribute to daylight optimisation across different climatic contexts. The study highlights the potential of biomimicry-inspired façade systems to support sustainable and energy-efficient urban building design.

Keywords: *Artificial Lighting; Biomimicry; Urban Buildings.*

1. INTRODUCTION

Urban areas are among the largest consumers of energy and natural resources, and their rapid expansion intensifies environmental and sustainability challenges. The continuous

[1] Undergraduate, Department of Building Economics, University of Moratuwa, Sri Lanka, weeranayakapaddj.21@uom.lk
[2] Temporary Instructor, Department of Building Economics, University of Moratuwa, Sri Lanka, bandararmhr.20@uom.lk
[3] Professor, Department of Building Economics, University of Moratuwa, Sri Lanka, mthayaparan@uom.lk

growth of cities increases the demand for buildings, infrastructure, and services required to support growing populations (Katabaro et al., 2022). This rapid urbanisation has significantly increased the demand for energy intensive buildings and infrastructure, resulting in higher consumption of natural resources and increasing environmental pressures. (Montes-Villalva et al., 2022). Consequently, improving the energy efficiency and environmental performance of buildings has become a critical priority for sustainable urban development.

Among the various operational energy demands in buildings, artificial lighting represents a considerable portion of electricity consumption. Lighting systems are essential for ensuring visual comfort and supporting building functionality; however, they contribute significantly to overall building energy use (Hong & Rahmat, 2022; Villalva et al., 2022). The extensive reliance on artificial lighting is often caused by insufficient access to natural daylight within building interiors, particularly in dense urban environments where surrounding structures limit daylight penetration. As a result, many buildings depend heavily on electric lighting during daytime hours, increasing operational energy consumption, building operating costs, and associated carbon emissions (Papamichael et al., 2018).

In response to growing environmental concerns, a substantial body of research has explored strategies to improve building energy efficiency (Kaitouni et al., 2024). In addition, the development of energy efficient lighting technologies such as LED systems, daylight sensors, and automated lighting controls has contributed to reducing electricity consumption in buildings (Vitalii et al., 2020). While these technological advancements have improved building performance, relatively limited attention has been given to architectural design strategies inspired by natural systems that could enhance daylight distribution within buildings and reduce reliance on artificial lighting.

Biomimicry has emerged as a promising approach for addressing sustainability challenges in the built environment. Biomimicry involves learning from and emulating natural forms, processes, and systems to develop innovative solutions to human design challenges (Hussein & Abbood, 2024). Natural systems demonstrate highly efficient mechanisms for regulating, filtering, and distributing light, offering valuable insights for daylight optimisation in buildings. Despite increasing interest in biomimicry within sustainable design research, its application for improving daylight performance and reducing artificial lighting demand in urban buildings remains relatively underexplored (Verbrugghe et al., 2023). Therefore, further investigation is required to understand how biomimicry-inspired daylighting strategies can be effectively integrated into contemporary building design. Accordingly, this study investigates how biomimicry-inspired daylighting strategies can reduce artificial lighting demand in urban buildings.

This study aims to evaluate biomimicry-inspired daylighting strategies in urban buildings by analysing selected case studies that incorporate nature-inspired façade systems. The research examines how these strategies improve daylight distribution and reduce reliance on artificial lighting.

2. LITERATURE REVIEW

2.1 DAYLIGHTING IN SUSTAINABLE BUILDINGS

Daylighting refers to the use of natural sunlight to illuminate indoor environments through architectural elements such as windows, skylights, and façade openings. It is widely recognised as a key strategy in sustainable building design because it reduces reliance on artificial lighting and lowers building energy consumption (Reinhart & Wienold, 2011) Lighting accounts for a significant proportion of electricity use in buildings; therefore, maximising daylight utilisation can contribute substantially to energy efficiency and improved environmental performance (Overen et al., 2023).

Beyond energy savings, daylighting enhances indoor environmental quality by improving visual comfort, occupant wellbeing, and productivity. Studies indicate that access to natural daylight can improve occupants' visual performance and psychological comfort compared with artificial lighting environments (Villalva et al., 2022). As urban populations continue to grow and cities become more densely developed, the role of daylighting in reducing energy consumption and improving indoor environmental quality has become increasingly important (Katabaro et al., 2022).

However, conventional daylighting strategies face several limitations, particularly in modern urban buildings. Deep plan building layouts often restrict daylight penetration into interior spaces, resulting in uneven light distribution and increased reliance on artificial lighting. In addition, high rise urban environments frequently experience shading from surrounding buildings, which reduces the effectiveness of traditional daylight design approaches. Excessive sunlight entering through large, glazed façades can cause glare and visual discomfort for occupants while increasing solar heat gain and cooling demand (Overen et al., 2023)

These challenges highlight the importance of façade design in contemporary daylighting strategies. Building façades play a critical role in controlling daylight penetration, reducing glare, and distributing light more evenly within interior spaces. As a result, innovative façade systems are increasingly being explored to improve daylight performance while maintaining thermal comfort and energy efficiency in buildings.

2.2 BIOMIMICRY IN ARCHITECTURAL DESIGN

Biomimicry is a design approach that studies nature's strategies and applies biological principles to solve human design challenges. Natural systems have evolved over millions of years to develop efficient, adaptive, and resource efficient solutions, making them valuable models for sustainable design in the built environment (Verbrugghe et al., 2023). In architecture, biomimicry encourages designers to observe natural forms, processes, and ecosystems and translate them into innovative building technologies and systems (Minucciani & Onay, 2018).

Biomimicry can be applied at multiple levels in architectural design. At the organism level, designers imitate the physical form or structure of biological organisms. At the behaviour level, the focus shifts to how organisms interact with their environment, such as plants adjusting their orientation toward sunlight (Pedersen-Zari, 2020). The ecosystem level considers broader environmental relationships and encourages buildings to function as integrated systems that efficiently manage energy, materials, and environmental conditions (Zari, 2020).

Several built environment projects illustrate the application of biomimicry principles in architecture. The Eden Project in the United Kingdom demonstrates organism-level biomimicry, where the structural geometry of the domes was inspired by soap bubbles and pollen grains. This design enables large spaces to be enclosed with minimal material while maximising natural light penetration and structural efficiency (Sydney's one central park, n.d.). Another example is One Central Park in Australia, which represents biomimicry at the ecosystem level. The project integrates vertical gardens and reflective systems inspired by forest ecosystems to improve daylight access, enhance environmental performance, and support urban biodiversity (Sydney's one central park, n.d.)

These examples demonstrate how biomimicry can enhance building performance by integrating natural principles into architectural design, particularly in areas such as ventilation, structural efficiency, and environmental responsiveness.

2.3 BIOMIMICRY FOR DAYLIGHTING OPTIMISATION

Nature provides numerous examples of systems that effectively regulate light and environmental conditions. These natural mechanisms have inspired innovative architectural strategies aimed at improving daylight performance in buildings. For example, the human iris controls the amount of light entering the eye through adjustable apertures, which has inspired adaptive façade systems capable of regulating daylight penetration (Verbrugghe et al., 2023). Similarly, honeycomb structures found in beehives provide efficient geometric patterns that distribute light evenly while maintaining structural stability (Sommese et al., 2024; Varshabi et al., 2022).

Plant mechanisms also provide valuable models for architectural design. Plant stomata regulate gas exchange and respond dynamically to environmental conditions, inspiring responsive building skins that adjust openings to control light and airflow (Bijari et al., 2025). In addition, natural structures such as fruit shells provide protective shading from excessive sunlight, influencing the design of architectural shading devices that reduce glare and solar heat gain (Bijari et al., 2025).

These biomimetic strategies offer several advantages for daylighting design. They enable more diffuse daylight distribution within interior spaces, reduce glare, and improve daylight autonomy, thereby decreasing dependence on artificial lighting systems (Minucciani & Onay, 2018) These biomimetic strategies are increasingly reflected in contemporary architecture, particularly in adaptive façade systems designed to regulate daylight penetration and improve visual comfort in buildings.

3. METHODOLOGY

This study adopts a comparative multiple case study research design to evaluate the effectiveness of biomimicry-inspired daylighting strategies in reducing artificial lighting demand in urban buildings. The case study approach was selected because it enables an in-depth examination of real-world architectural applications of biomimicry and allows comparison of design strategies implemented in different climatic and urban contexts. Unlike experimental or simulation-based studies, this method focuses on analysing existing buildings where biomimetic principles have already been applied in façade systems or daylighting design, providing practical insights into their performance and applicability.

This research specifically adopts an exploratory secondary-data-based multiple case study approach. Five international case studies were selected based on three main criteria: (1) the integration of biomimicry-inspired façade or daylighting concepts, (2) the availability of documented architectural and daylighting performance information, and (3) representation of diverse climatic and urban conditions. The selected buildings include Institut du Monde Arabe (France), Sinosteel International Plaza (China), Habitat 2020 (China), Esplanade Theatres on the Bay (Singapore), and Al Bahar Towers (UAE). These projects represent a range of biomimetic inspirations, including the human iris, honeycomb structures, plant stomata, and natural shell geometries, which are translated into adaptive or passive façade systems to regulate daylight penetration.

Data were collected entirely from secondary sources including peer-reviewed journal articles, architectural reports, case study publications, and documented performance evaluations of the selected buildings. The collected information included building characteristics, biomimicry inspiration, façade configuration, daylighting mechanisms, and reported performance indicators such as daylight autonomy, useful daylight illuminance ranges, glare control performance, and artificial lighting reduction outcomes.

To ensure consistency in analysis, each case study was examined using a structured comparative framework consisting of five parameters: biomimicry inspiration, architectural translation of the biological principle, daylighting mechanism, performance outcomes related to daylight distribution, and implications for artificial lighting reduction. A cross-case comparative analysis was then conducted to identify recurring biomimicry strategies and evaluate their effectiveness across different climatic conditions and building functions. This analytical approach enabled the identification of key design patterns that contribute to improved daylight penetration and reduced reliance on artificial lighting in urban buildings.

4. CASE STUDY ANALYSIS

This section evaluates biomimicry strategies applied in urban building construction to reduce artificial lighting demand. Each case study is structured around: building overview, biomimicry inspiration, daylighting mechanism, performance impact, and design implications.

4.1 INSTITUT DU MONDE ARABE - FRANCE

Figure 1: (a) Institut du Monde Arabe, France (Winstanley, 2011) (b) Façade system (Winstanley, 2011), (c) Human eye's iris (Science Photo Gallery, n.d.)

4.1.1 Building Overview

The 28,000 m² Institut du Monde Arabe (Paris, France) [refer Figure 1:(a)] by Jean Nouvel functions as a cultural centre housing exhibition space, a library, auditorium, and offices. Its south facing façade [refer Figure 1:(b)] features 240 motorised panels with 30,000 photosensitive apertures (Winstanley, 2011).

4.1.2 Biomimicry Inspiration

Inspired by the human eye's iris [refer Figure 1:(c)] and traditional Arabic Mashrabiya (ornate wooden or metal lattice screens historically used in Islamic architecture), the facade dynamically adapts to varying light levels, combining cultural symbolism with biological responsiveness (Michler, 2010a).

4.1.3 Daylighting Mechanism

The motorised diaphragms respond to external illuminance via photoelectric sensors, adjusting aperture size to allow diffused daylight while blocking direct sun. Wider openings occur on overcast days; tighter closures mitigate glare from low winter or high summer sun (Michler, 2010b; Winstanley, 2011).

4.1.4 Performance Impact

The adaptive façade system significantly improves daylight performance within the building. Studies indicate that the dynamic aperture mechanism enables the building to maintain high levels of daylight autonomy while reducing dependence on artificial lighting. Reported performance evaluations suggest that the system achieves approximately 30–50% reduction in artificial lighting energy, while maintaining useful daylight illuminance levels across interior spaces (Jamilu et al., 2024). The adjustable apertures diffuse incoming sunlight, thereby minimising glare and improving visual comfort for occupants (Attia et al., 2015).

4.1.5 Design Implications

The IMA demonstrates biomimicry's potential for responsive daylight control in temperate climates. Lessons include integrating hybrid sensor driven systems for improved durability and energy efficiency (Attia et al., 2015).

4.2 SINOSTEEL INTERNATIONAL PLAZA - CHINA

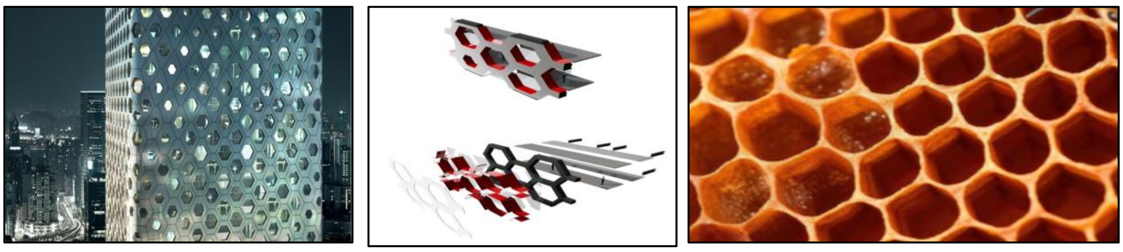

Figure 2: (a) Sinosteel International Plaza, China (Bojovic, 2013), (b) Façade system (Bojovic, 2013), (c) Beehive hexagonal cells (Freepik, n.d.)

4.2.1 Building Overview

Sinosteel International Plaza (Tianjin, China) [refer Figure 2:(a)], designed by MAD Architects, comprises a 358 m office tower and 88 m hotel tower with a total GFA of

350,000 m². The honeycomb inspired facade emphasises structural efficiency and daylight optimisation (Etherington, 2008).

4.2.2 Biomimicry Inspiration

Inspired by beehive hexagonal cells [refer Figure 2:(c)], the façade [refer Figure 2:(b)] uses geometry to maximise daylight diffusion, structural strength, and minimal material usage while integrating traditional Chinese motifs (Bojovic, 2013).

4.2.3 Daylighting Mechanism

Variable hexagonal openings in the honeycomb pattern are sized according to solar exposure, reducing glare and distributing diffuse light throughout interior spaces without kinetic elements (Sino-Steel International Plaza, n.d.).

4.2.4 Performance Impact

The honeycomb-inspired façade contributes to improved daylight distribution through passive geometric modulation. The hexagonal façade pattern allows diffuse daylight to penetrate interior spaces while reducing excessive solar exposure. As a result, the building achieves improved daylight autonomy and reduced reliance on artificial lighting systems. Previous studies estimate that the façade design contributes to 20–30% reductions in lighting and cooling energy demand, particularly in high-density urban environments (Villalva et al., 2022; Etherington, 2008).

4.2.5 Design Implications

The project illustrates how passive biomimetic strategies using parametric geometry can optimise daylight in high density urban environments while maintaining cultural resonance (Etherington, 2008).

4.3 HABITAT 2020 - CHINA

Figure 3: (a) Habitat 2020 conceptual design, (b) Facade system (Yoneda, 2008)

4.3.1 Building Overview

Habitat 2020 is a conceptual biomimetic housing project [Figure 3: (a)] aiming for off grid, adaptive, eco systemic urban habitats with dynamic “living skin” facades [Figure 3:(b)] (Yoneda, 2008).

4.3.2 Biomimicry Inspiration

Inspired by plant stomata, the facade functions like a living organism, opening and closing in response to environmental stimuli to regulate light, air, and energy flows (Yoneda, 2008).

4.3.3 Daylighting Mechanism

Responsive panels modulate light entry, allowing diffuse daylight while blocking excessive sun. The system channels natural light deep into interiors, reducing shadows and hotspots (Yoneda, 2008).

4.3.4 Performance Impact

The conceptual design of Habitat 2020 demonstrates the potential of organism-level biomimicry for daylight optimisation. The responsive façade system, inspired by plant stomata, dynamically regulates light penetration according to environmental conditions. This adaptive mechanism allows daylight to penetrate deeper into interior spaces while minimising excessive solar radiation. Conceptual performance evaluations indicate that such responsive systems could reduce artificial lighting demand by 50–80%, while maintaining high daylight autonomy and useful daylight illuminance levels (Sommese et al., 2024; Yoneda, 2008).

4.3.5 Design Implications

Habitat 2020 demonstrates the potential of organism-level biomimicry for self-sustaining, daylight optimised urban habitats, though real world implementation challenges remain (Sommese et al., 2024).

4.4 ESPLANADE THEATRE - SINGAPORE

Figure 4: (a) Esplanade Theatre, Singapore, (b) Facade system, (c) Durian fruit

4.4.1 Building Overview

The 60,000 m² Esplanade Theatre (Marina Bay, Singapore) [refer Figure 4:(a)] by DP Architects and Michael Wilford features concert halls, studios, and public spaces. Its signature façade [refer Figure 4:(b)] is clad with 7,000+ triangular Aluminium sunshades (Architecture, n.d.).

4.4.2 Biomimicry Inspiration

Inspired by the durian fruit shell [refer Figure 4:(c)], the sunshade geometry provides passive shading and light diffusion for equatorial conditions (Esplanade Theatres, 2025).

4.4.3 Daylighting Mechanism

Parametrically varied triangular sunshades block direct sun and create dappled interior illumination, maintaining uniform daylight levels while minimising glare (Chayaamor-Heil, 2023).

4.4.4 Performance Impact

The durian-inspired façade of the Esplanade theatre demonstrates the effectiveness of passive biomimetic shading strategies in tropical climates. The triangular Aluminium sunshades filter incoming sunlight and create diffuse interior illumination, which improves daylight distribution throughout the building. This design significantly reduces glare while maintaining comfortable lighting levels in public interior spaces. Performance studies indicate that the façade system contributes to approximately 55% reduction in artificial lighting demand, while also improving overall building energy efficiency (Chayaamor-Heil, 2023; Esplanade Theatres, 2025).

4.4.5 Design Implications

The Esplanade highlights durable, fixed biomimetic shading as a solution for tropical climates, integrating environmental, aesthetic, and cultural objectives (Biomimicry Architecture #3, 2019).

4.5 AL BAHAR TOWERS - UAE

Figure 5: Al Bahar Towers, UAE, (b) Facade system, (c) Pinecone

4.5.1 Building Overview

Al Bahar Towers (Abu Dhabi, UAE) [refer Figure 5:(a)], designed by Aedas, are twin 145 m office towers featuring over 2,000 motorised triangular mashrabiya panels (Attia, 2016; Cilento, 2012).

4.5.2 Biomimicry Inspiration

Combining traditional Mashrabiya with pinecone [refer Figure 5:(c)] and flower inspired movements, the kinetic façade [refer Figure 5:(b)] opens/closes according to sun position, offering adaptive shading in a hot desert climate (Attia, 2016; Cilento, 2012).

4.5.3 Daylighting Mechanism

Photoelectric sensors control panel movement to maximise diffuse daylight while minimising glare. Panels adjust for morning, evening, and peak sun exposure, preserving interior comfort and views (Attia, 2016).

4.5.4 Performance Impact

The kinetic Mashrabiya façade of Al Bahar Towers demonstrates the effectiveness of responsive shading systems in hot desert climates. The motorised triangular panels automatically adjust according to solar position, allowing diffuse daylight while limiting excessive solar radiation. This adaptive mechanism improves daylight penetration and reduces glare within office spaces. Performance assessments indicate that the façade contributes to 30–50% reduction in artificial lighting energy consumption, while improving daylight autonomy across interior floor areas (Attia, 2016; Cilento, 2012).

4.5.5 Design Implications

Al Bahar Towers exemplify kinetic, culturally informed biomimicry for extreme climates (refer Table 1).

Table 1: Comparative Analysis of Case Studies

Building	Biomimicry Inspiration	Daylighting Strategy	Artificial Lighting Reduction
Institut du Monde Arabe, France	Human eye iris	Motorized photo-sensitive apertures adjust to external illuminance levels	30-50%
Sinosteel International Plaza, China	Honeycomb structure	Passive hexagonal window pattern diffuses daylight	20-30%
Habitat 2020, China	Plant stomata	Responsive dynamic facade panels for diffuse light	50-80% (conceptual)
Esplanade Theatre, Singapore	Durian fruit shell	Triangular aluminium sunshades block direct sunlight, diffuse light	55%
Al Bahar Towers, UAE	Flowers / pinecones	Motorized panels open/close with sun position to optimize daylight	30-50%

Despite mechanical complexity and maintenance needs, the towers achieve substantial lighting efficiency and occupant comfort (Cilento, 2012).

4.6 ANALYTICAL DISCUSSION

Table 1 highlights key patterns in biomimicry inspired daylight strategies. Kinetic versus passive facades show distinct performance trade-offs: motorised facades (Institut du Monde Arabe, Al Bahar Towers) allow precise daylight control but involve higher maintenance and mechanical complexity, whereas passive systems (Sinosteel, Esplanade) offer simpler, lower maintenance solutions through geometry and orientation. Climate influence is evident: hot arid regions e.g. Abu Dhabi favour kinetic shading to mitigate intense solar gain and glare, whereas temperate or tropical regions benefit from diffusive passive shading. The range of artificial lighting reduction varies widely from 20-80%, with dynamic responsive systems achieving the highest potential savings, while passive strategies provide consistent, moderate energy reductions. These patterns demonstrate biomimicry's versatility in enhancing daylight autonomy while balancing operational practicality and cultural design considerations. As an exploratory comparative analysis based on secondary data sources, these findings should be interpreted cautiously and considered as a conceptual foundation for more detailed future investigations involving simulation modelling, occupant-level measurements, and empirical energy performance analysis.

5. DISCUSSION

These findings contribute to the growing discourse on form- and behavior-driven daylight optimisation as a key strategy for decarbonising the built environment. The comparative analysis of the case studies indicates that adaptive and passive biomimicry strategies can reduce artificial lighting demand by 20-80%, depending on climate, façade complexity, and building type. Unlike conventional daylighting studies that primarily attribute energy reductions to technological interventions or glazing modifications, this analysis isolates the role of biomimetic geometry and dynamic façade behavior as the principal variable influencing daylight performance. By maintaining consistent building envelope materials and environmental conditions across projects, the attribution of performance improvements to adaptive forms is reinforced.

Exemplar projects, such as the Institut du Monde Arabe and Al Bahar Towers, demonstrate kinetic strategies where motorised apertures respond to solar intensity and orientation, modulating interior light levels and reducing glare. In contrast, passive systems such as the Sinosteel International Plaza and Esplanade theatre, Singapore rely on geometric or parametric shading patterns to diffuse sunlight and optimise daylight distribution. Analytical comparison shows that kinetic systems offer finer control over illumination and glare but incur higher maintenance complexity and operational costs. Passive geometric systems provide lower maintenance solutions, yet their performance is constrained by the fixed orientation and climatic conditions, highlighting the trade-offs inherent in façade strategy selection.

Climate influence emerges as a critical determinant of system effectiveness. Hot-arid climates, as in Abu Dhabi, benefit from responsive kinetic shading to mitigate extreme solar gains, while tropical contexts, exemplified by Singapore, achieve adequate daylighting through fixed parametric or modular patterns. These results align with prior studies (Etherington, 2008), yet the present analysis emphasises the interaction between climate, form, and dynamic behavior as a measurable factor in operational energy reduction, rather than merely aesthetic or conceptual innovation.

Several limitations must be acknowledged. Quantitative data on occupant-level illumination and energy savings remain limited, particularly for conceptual projects such as Habitat 2020, where performance modeling is theoretical rather than empirically validated. Additionally, the long-term operational impacts, such as façade maintenance requirements, mechanical wear, and lifecycle performance of kinetic systems, are not fully captured within the current evaluation. Since the study relies entirely on documented secondary data sources, the findings should be considered exploratory and suitable as a foundation for more detailed future studies involving simulation modelling and empirical performance validation. Despite these constraints, the findings underscore the potential of early stage morphological and geometric interventions to enhance visual comfort and reduce artificial lighting reliance, independent of changes to building systems or occupancy patterns.

Taken together, these results position biomimicry inspired daylighting not merely as a symbolic or aesthetic exercise, but as a quantifiable, form and behavior driven strategy with implications for sustainable architecture, lifecycle energy modeling, and adaptive urban design. By integrating multiple passive and kinetic functions such as light modulation, glare reduction, and solar control within a coherent morphologically inspired envelope, these designs mirror ecological principles where structures often perform multiple functions simultaneously, offering a resilient and energy efficient logic for future buildings.

6. CONCLUSIONS

This study evaluated the effectiveness of biomimicry-inspired daylighting strategies in reducing artificial lighting demand in urban buildings through the analysis of five international case studies. The findings demonstrate that nature-inspired façade systems, including adaptive apertures, honeycomb geometries, responsive skins, and parametric shading structures, significantly enhance daylight penetration and interior illumination while reducing reliance on artificial lighting. The comparative analysis indicates that both passive and kinetic biomimetic façade strategies can improve daylight distribution and reduce lighting energy consumption, with reductions ranging from approximately 20–80% depending on climatic context and façade configuration.

The results highlight the importance of integrating biological principles into architectural design to improve building environmental performance. Biomimicry-inspired daylighting strategies provide a promising approach for achieving energy-efficient and climate-responsive urban buildings. Future research should further explore parametric modelling, adaptive façade technologies, and advanced materials to develop scalable biomimetic design solutions that optimise daylight utilisation in contemporary urban architecture.

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