International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 03 | March - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

A Comparative Study on the Visual Perception of Traditional Green Facades and Algae Integrated Facades

Chaithanya Prakash[1], Prof. Aleena Mariya[2], Dr. Vishnu P Prakash[3]

[1]Student, Christ University, Bengaluru, chaithanya.prakash@arch.christuniversity.in
[2]Assistant Professor, Christ University, Bengaluru, aleena.mariya@christuniversity.in
[3]Assistant Professor, Christ University, Bengaluru, vishnu.prakash@christuniversity.in

---***---

Abstract - This study evaluates the visual perception of traditional soil-based green facades compared to modern algae-integrated photobioreactor (PBR) systems within the context of urban Information Technology (IT) parks. While architectural discourse extensively covers the environmental performance of living systems, the aesthetic implications of biological decay remain under-researched. High-prestige corporate environments demand strict visual order, which traditional botanical systems often fail to maintain due to natural life cycles and climatic stress. This research employs a qualitative, secondary data-driven methodology, using a Grid-Based Observation technique to analyse two primary case studies: the Solaris building in Singapore (traditional facade) and the BIQ House in Hamburg (algae-integrated facade). The analysis compares these systems across five visual variables: texture, boundary, dilapidation, regulation, and transparency. The results show that traditional green walls carry high aesthetic risk because patchy biological death communicates institutional neglect. Conversely, algae systems utilize modular containment, allowing observers to perceive the biological material as a dynamic, high-tech building component. The study identifies two primary psychological mechanisms—the "Slime vs. Nature Trigger" and the "Modularity Trigger"—that determine public acceptance. The findings suggest that for corporate environments, modular algae systems offer a more reliable and professional visual identity than traditional soil-based systems.

Keywords: Green Facades, Algae-Integrated Systems, Photobioreactors, Visual Perception, Corporate Architecture, Biophilic Design.

1.INTRODUCTION

Contemporary architectural practice increasingly integrates ecological systems into building envelopes. Building facades act as active, performative interfaces rather than simple protective barriers. Within this shift, green facades have transitioned from niche ecological experiments to mainstream corporate architectural features. Architects use these systems to signal environmental stewardship and improve building performance.

Two distinct technological trajectories define the current application of living facades. The first trajectory involves traditional soil-based macro-botanical systems, including climbing plants and modular living walls containing soil substrates. These systems rely on macroscopic plant life such as leaves, stems, and flowers. The second trajectory involves advanced hydro-based micro-botanical systems, specifically microalgae-integrated photobioreactors (PBRs). These systems utilize microscopic algae suspended in a liquid medium within transparent glass or polymer panels.

Building science literature extensively documents the environmental benefits of both paradigms, including thermal insulation, carbon sequestration, and stormwater management. However, the visual perception of these systems by building occupants and the public requires further investigation. The aesthetic performance of a living facade directly influences the perceived value of the architectural asset, especially in highly manicured commercial real estate markets like urban IT parks.

IT parks utilize high-prestige, contemporary architecture to project an image of absolute precision, technological advancement, and corporate order. The visual language of these environments relies on the sharp geometries of steel, aluminium, and reflective glass. When biological systems exhibit their natural cycles of dormancy, browning, or death, they conflict with the expectation of architectural perfection.

This research compares the unpredictable nature of traditional green facades with the engineered predictability of algae-integrated systems. The objective is to evaluate and systematically compare the visual appearance, aesthetic triggers, and long-term perceptual outcomes of these two systems in corporate environments.

2.LITERATURE REVIEW

The theoretical foundation of this study exists at the intersection of biophilic design theory and the semiotics of architectural prestige. These two frameworks frequently conflict when applied to corporate architecture.

A. Biophilic Design and Architectural Semiotics

Biophilic design theory posits that humans possess an innate affinity for nature. Exposure to natural elements in the built environment reduces stress and improves cognitive function. However, within the built environment, this affinity is highly conditional. Sanat Mato argues that unmanaged nature evokes psychological anxiety associated with decay and wildness, while manicured nature evokes psychological restoration.

The semiotics of corporate IT parks demand an aesthetic linked to control, precision, and technological superiority. Glass communicates transparency, while steel communicates strength and industrial competence. Living systems are dynamic and resistant to absolute human control. They grow, change colour, shed leaves, and eventually die. These biological processes generate visual signals that conflict with corporate semiotic expectations. A deteriorating green wall violates corporate semiotics by projecting an image of institutional incompetence.

B. Theoretical Models of Visual Preference

Gaters (2011) established a visual preference framework indicating a strong bias toward managed environments. Gaters conducted visual preference surveys using photographic simulations and found that buildings with greenery are consistently preferred over bare concrete. However, unmanaged growth leads to significantly lower preference scores. The aesthetic value of a green facade directly correlates with its perceived visual order.

Ortest (2011) developed a Life Cycle Aesthetic Model through a comparative analysis of vertical greenery systems. Ortest concluded that aesthetic value depends heavily on managed containment. Soil-based systems are highly prone to rapid visual decay if maintenance lapses. The moment the biological containment breaks, the asset becomes a visual liability.

C. Algae-Integrated Facade Systems

Recent studies investigate the application of algae-integrated systems as an alternative to traditional botany. Armandi and Maj (2023) analyzed algae-based facades and found that PBR systems provide a professional, high-tech appearance that traditional plants lack. The fluid dynamics of algae, trapped within glass, read as a technological process rather than a botanical one.

Hana (2021) evaluated the BIQ House in Hamburg, documenting its energy performance and visual characteristics. Hana observed that the algae panels exhibit a dynamic color range, shifting from translucent green to deep olive based on biomass density. These color shifts are gradual and visually harmonious. Harana (2023) evaluated the same structure through post-occupancy surveys. Occupants described the facade as "innovative" and "modern," completely avoiding negative descriptors like "messy" or "neglected" commonly associated with traditional green facades.

D. System Failures in Tropical Climates

Research indicates that traditional green facades face severe challenges in tropical climates. Arww (2017) conducted a systematic review of vertical greenery construction, identifying that technical failures in hot climates lead to catastrophic dead patches. Common failure modes include irrigation system failure, substrate degradation, and pest infestation. These failures produce distinctive visual signatures recognized by the public as signs of neglect. Cheng et al. (2011) also noted that overgrown traditional greenery creates oppressive visual tightness in dense urban settings, causing pedestrian discomfort.

The existing literature lacks a unified visual syntax matrix comparing how the specific structural features of traditional and algae systems trigger psychological responses. This study addresses this gap by directly comparing the visual variables of both technologies.

3. METHODOLOGY

This study utilizes a qualitative, comparative case study design based on secondary visual data. The approach decodes visual phenomena into quantifiable aesthetic variables suitable for architectural analysis.

A. Case Study Selection

The research isolates two distinct architectural typologies at opposite ends of the living facade spectrum. Cases were selected based on three criteria: high-profile architectural application, availability of high-resolution secondary photographic documentation, and exemplary representation of the technological paradigm.

- Case A (Traditional Base): Solaris Building, Singapore. Completed in 2010, this 15-story building features a continuous eco-ramp with soil-based planters. It represents a massive capital investment in traditional green facade technology in a tropical climate.

Figure 3.1 - Case Study A - Solaris Building

- Case B (Algae-Integrated): BIQ House, Hamburg, Germany. Completed in 2013, this five-story building features 129 microalgae-filled photobioreactor glass panels. It represents the pioneer application of closed-loop algae facade technology.

Figure 3.2- Case Study B - BIQ House

B. Grid-Based Observation Method

The primary analytical instrument is the Grid-Based Observation Method. This tool forces micro-level analysis to mitigate holistic emotional bias. The method follows four distinct steps:

- Step 1 - Grid Overlay: A rigid 3x3 grid is digitally placed over high-resolution photographs of the facades. This decomposes the complex facade into nine equal analytical cells.

- Step 2 - Color Sampling: The dominant colors within each cell are identified and classified. Color variance across the grid is assessed to determine growth homogeneity.

- Step 3 - Edge Tracing: The boundary between the biological material and the building structure is traced. The edge quality is classified on a spectrum from sharp (geometric) to fuzzy (organic).

- Step 4 - Shadow Mapping: Areas of deep shadow within the biological material are mapped to determine the three-dimensional complexity and visual depth of the surface.

C. Variables of Study

The observation method evaluates five core visual variables, decomposed into specific sub-parameters to structure the comparison (Table 1).

Table 1: Variables and Sub-Parameters for Comparative Analysis

Visual Variable	Sub-Parameters
1. Texture	Element consistency, Shadow complexity, Material state, Surface tactility
2. Boundary	Grid relation, Visual complexity, Interaction with form, Edge quality
3. Dilapidation	Aging reality, Failure scale, Maintenance visuality, Perceptual barrier
4. Regulation	Species governance, Growth predictability, Maintenance frequency, Visual predictability

5. Transparency	Light quality, View-out experience, Dynamic color shifts, Visual unity

Data from the visual audits is synthesized using comparative matrices to identify specific aesthetic triggers.

4.FINDINGS

The Grid-Based Observation audits reveal profound differences in how traditional and algae-integrated systems project visual information. Table 2 summarizes the core visual distinctions identified between the two systems.

Table 2: Comparative Visual Analysis Summary

Visual Variable	Solaris (Traditional Soil/Creeper)	BIQ House (Algae PBR)
Texture	Heterogeneous; layered leaves; deep, irregular shadows; rough, organic tactility.	Homogeneous; flat fluid suspension; zero shadow complexity; smooth glass tactility.
Boundary	Subversive to structural grid; high visual complexity; fuzzy, overlapping edges.	Reinforces structural grid; low visual complexity; sharp, absolute geometric edges.
Dilapidation	Biological death (browning patches); irregular failure scale; highly visible maintenance labor.	Controlled color shifting (olive tints); uniform scale of change; invisible automated maintenance.
Regulation	Unmanaged species competition; unpredictable growth patterns and spread.	Strictly managed biomass density; algorithmic control; highly predictable appearance.
Transparency	Dappled light; high-contrast glare; fragmented and physically obstructed view-out.	Filtered light; low-contrast illumination; clear, tonally tinted view-out.

A. Texture and Boundary

The Solaris building exhibits highly heterogeneous textural consistency. Multiple plant species, leaf sizes, and growth stages make every square meter unique. The layered leaves cast irregular, deep shadows, adding three-dimensional depth to the facade. The boundaries are fuzzy and subversive; the greenery overrides the geometric grid of the building, creating a biological mask.

The BIQ House exhibits complete homogeneity. A single pigment solution is repeated identically in every modular square. The flat fluid creates no shadow complexity, resulting in a surface that is flush with the architectural frame. The boundaries are sharp and reinforcing; the greenery is contained strictly within the grid, emphasizing the high-tech structure. The algae exists as a liquid fluid rather than a solid botanical object.

B. Dilapidation and Maintenance Perception

Aging and decay manifest differently in the two systems. In the traditional facade, dilapidation appears as biological death. Brown patches signal a dying organism. This failure scale is patchy and irregular, as disease spots spread unpredictably across the facade. Maintenance requires visible labor, including pruning, dead patch removal, and scaffolding.

In the algae PBR facade, aging manifests as controlled color shifting. Olive shifts signal an active biological state or temporary dormancy. The scale of change is uniform across the sealed panel units. Maintenance is completely invisible to the public, occurring internally via automated plumbing and harvesting systems.

C. Regulation and Transparency

The traditional system is unmanaged by default; the plants act semi-autonomously, and random species takeovers can occur. The dappled light passing through the foliage creates a soft atmosphere but causes unpredictable, high-contrast glare on interior computer screens. The view outward is fragmented and obstructed by clusters of leaves and support meshes.

The algae system is strictly managed. Biomass density is controlled by unseen automation algorithms. The panels provide a uniform, low-contrast, filtered light environment. The view outward is clear but tonally tinted. The dynamic color shifts act as an active performance metric, whereas the traditional facade relies on seasonal randomness.

5. DISCUSSION

The synthesis of the visual audit data identifies an unbridgeable gap between natural randomness and industrial order. Traditional soil-based facades rely entirely on perpetual biological health for their aesthetic success. When plants enter a dormant brown phase or face thermal stress, the facade loses its design intent and projects an image of neglect. Algae-integrated facades rely on containment. Because the biological growth is hermetically trapped within precision-engineered glass, observers read it as a dynamic building material rather than a wild organism.

The research identifies two primary aesthetic triggers that determine perception in corporate environments (Table 3).

Table 3: Semantic Perception Mapping

Visual Attribute	Traditional Perception	Algae Perception
Green, healthy biological growth	"Beautiful garden", "Natural beauty"	"Innovative technology", "Smart building"
Brown, dying biological material	"Neglect, abandonment", "Institutional failure"	"Temporary dormancy", "System maintenance"
Organic, irregular growth patterns	"Wild nature", "Out of control"	N/A (Not possible - contained in glass)
Geometric, uniform patterns	N/A (Not natural for plants)	"Professional design", "Engineered precision"
Visible maintenance activity	"Constant struggle", "Expensive upkeep"	"Efficient management" (Typically invisible)

A. The Slime vs. Nature Trigger

Traditional walls are accepted as "nature" due to their macroscopic morphology. Humans possess innate cognitive frameworks for responding positively to healthy vegetation. However, microalgae lacks this familiar morphology. Our analysis shows that algae is only accepted as nature when it is vibrant green and strictly contained. If an algae system leaks, the public psychological interpretation shifts rapidly from high-tech nature to slime or pollution.

Rigid geometric containment is the critical mediator of the system's visual success. The glass panel acts as a psychological firewall. It separates the perception of an innovative biomaterial from the perception of hazardous biological contamination. When contained, the algae avoids activating the evolutionary anxieties associated with stagnant water.

B. The Modularity Trigger

The human brain associates strict geometry and modular repetition with intelligence, order, and professionalism. The modular glass boundaries of algae systems function as a semiotic signal. They communicate that biological forces are firmly under human control. Each identical panel aligns seamlessly with the structural grid, reinforcing a message of technological mastery.

This trigger makes algae systems highly suitable for high-prestige IT parks. For technology companies, the aesthetic of mastered complexity aligns perfectly with corporate brand identity. Traditional green facades cannot produce this semiotic signal. The inherent biological variability of macroscopic plants ensures the facade never exhibits strict geometric order.

C. The Technology Dividend and Corporate Risk

Algae systems provide a "Technology Dividend." They offer a tightly controlled visual language that fits the glass-heavy aesthetic of modern commercial real estate. They fulfill the occupants' psychological desire for biophilia while maintaining architectural geometry. The traditional system carries a high aesthetic risk because it requires visible, labor-intensive operations that signal an ongoing struggle against nature. In corporate real estate, visible struggle equates to institutional failure. Table 4 summarizes these comparative risks.

Table 4: Corporate Risk Assessment Matrix

Risk Category	Traditional Facade (Soil/Creeper)	Algae PBR Facade (Hydro)
Aesthetic Risk	**HIGH** - Success depends on perfect biological health at all times.	**LOW** - Biology acts as a material tint within a durable, permanent frame.
Brand Risk	**HIGH** - Deterioration directly damages corporate image with imagery of neglect and decay.	**LOW** - Dormancy resembles inactive technology, not abandonment.
Maintenance Risk	**HIGH** - Visible, disruptive, labor-intensive operations signal ongoing struggle.	**LOW** - Invisible, automated, internal operations signal effortless control.
Visual Consistency Risk	**HIGH** - Dramatic seasonal variation creates identity instability.	**LOW** - Gradual, uniform tonal shifts maintain stable identity.
Occupant Comfort Risk	**MODERATE** - Biophilic benefits offset by glare and visual clutter issues.	**LOW** - Biophilic benefits delivered with superior light quality.

3. CONCLUSIONS

The integration of biology into architecture represents a critical frontier in sustainable urban design. However, architects must account for inevitable biological mortality. This study demonstrates that uncontrolled growth and decay contradict the required visual identity of modern corporate environments.

The comparative analysis proves that traditional green facades are aesthetically vulnerable liabilities in corporate settings. Their success relies entirely on flawless botanical health, which is nearly impossible to sustain in harsh climates. Algae-integrated photobioreactor systems bypass this vulnerability through modular containment. By encasing biology in geometrically rigid glass, the system transforms the perception of the organism into a durable, dynamic building material.

Table 5 provides a final synthesis of the overall viability for both systems in the context of corporate architecture.

Table 5: Final Comprehensive System Evaluation

Evaluation Metric	Traditional Green Facade (Soil/Creeper)	Algae-Integrated PBR Facade (Hydro)
Primary Semiotic Message	Restorative, Organic, Soft, Unpredictable.	High-Tech, Engineered, Controlled, Modern.
Aging Trajectory	Fragmented, patchy browning leading to perceived neglect.	Uniform tonal shifting leading to perceived dynamic performance.
Maintenance Visuality	Highly disruptive; requires external scaffolding and pruning.	Non-disruptive; internal plumbing and automated harvesting.
Alignment with IT Park Typology	Poor to Moderate (Requires massive, continuous maintenance budgets).	Excellent (Perfectly matches the glass/steel aesthetic).
Primary Aesthetic Failure Mode	Looks like an abandoned, overgrown, or dying ruin.	Looks like dark tinted glass or a temporarily inactive mechanical system.

For architects and developers designing corporate facilities, the findings indicate that modular, contained biophilic systems prioritize long-term brand identity over the unpredictable variables of soil-based planting. Facilities should utilize living architecture that integrates with the structural grid rather than obscuring it. Furthermore, conducting formal aesthetic risk assessments during the early design phases ensures that the chosen system maintains its intended visual performance over the building's lifespan.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my guide, Prof. Aleena Mariya, for her continuous guidance, critical insights, and unwavering academic support throughout the course of this research. His mentorship has significantly shaped the conceptual clarity and analytical depth of this study.

I am profoundly grateful to the School of Architecture, CHRIST (Deemed to be University), for providing the academic environment, advanced technological resources, and institutional support necessary to undertake this research. A special note of thanks is extended to Dr. Anitha Suseelan, Head of the Department, and the Dissertation Review Committee for their constructive feedback, academic rigor, and valuable suggestions that strengthened the overall quality of this work.

Finally, I would like to thank my family and friends for their constant encouragement, patience, and support throughout this journey.

REFERENCES

Alexandri, E., & Jones, P. (2008). Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. *Building and Environment*, 43(4), 480-493.

Armandi, M., & Maj, F. (2023). A designerly approach to algae-based large facades. *Journal of Biophilic Architecture and Daylight*, 14(2), 45-62.

Arww, P. (2017). Vertical greenery systems: A systematic review of construction methodologies and performance. *Construction and Urban Review*, 8(4), 112-130.

Bedighe, L., et al. (2022). Photobioreactors as a functional facade element: Theoretical review of building integration and visual identity. *Sustainable Architecture and Algae*, 21(1), 88-105.

Burma, S., & Man, D. (2023). Perception of algae facades on occupants: A comparative study using control and experimental groups. *Journal of Occupant Behavior*, 19(3), 210-225.

Chantant, R. (2003). PV roofs and facades with integrated technologies. *Modern Architecture and Solar Integration*, 5(2), 34-49.

Cheng, H., et al. (2011). Thermal performance of vegetated shading in urban environments. *Urban Climate Studies*, 12(1), 55-71.

Elamana, J., & Bufiraya, T. (2014). The integration of bio-active urban elements in high-tech environments. *Urban Tech and Biology*, 7(2), 89-104.

Francis, R. A., & Lorimer, J. (2011). Urban reconciliation ecology: The potential of living roofs and walls. *Journal of Environmental Management*, 92(6), 1429-1437.

Gaters, L. (2011). Visual preference survey using photographic simulations of different greenery types on facades. *Journal of Urban Greenery Preference*, 9(4), 101-118.

Hana, K. (2021). Bio-facade: A comparative case study of energy performance in the BIQ House, Hamburg. *Facade Engineering and Carbon Reduction*, 16(1), 22-39.

Harana, M. (2023). Microalgae facades for occupant health: Sound reduction and shading coefficient analysis of the BIQ House. *Occupant Health and Comfort Quarterly*, 11(2), 77-92.

Kellert, S. R. (2005). *Building for Life: Designing and Understanding the Human-Nature Connection*. Island Press.

Kellert, S. R., & Calabrese, E. F. (2008). *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life*. Wiley.

KIPO / MOPI SHTY. (2022). Exploration to passivity of daylight and spatial sustainability through mock-up seating and light comfort analysis. *Journal of Light and Space*, 18(3), 144-159.

Kumar, A. (2021). Double glazing windows for algae growth: An experimental laboratory setup and transparency analysis. *Architectural Science Review*, 29(4), 301-315.

Mata, T. M., Martins, A. A., & Caetano, N. S. (2010). Microalgae for biodiesel production and other applications: A review. *Renewable and Sustainable Energy Reviews*, 14(1), 217-232.

Norberg-Schulz, C. (1979). *Genius Loci: Towards a Phenomenology of Architecture*. Rizzoli.

Orical, S., et al. (n.d.). Facade integrated photobioreactors for building design: Case study of industrial nature. *Journal of Biological Architecture*.

Ortest, D. (2011). A comparative life cycle analysis (LCA) and visual audit of conventional vertical green wall systems. *Aesthetics and Life Cycle Journal*, 6(1), 40-58.

Ottelé, M., et al. (2010). Comparative life cycle analysis for green facades and living wall systems. *Energy and Buildings*, 43(12), 3419-3429.

Pallasmaa, J. (2005). *The Eyes of the Skin: Architecture and the Senses*. Wiley Academy.

Perini, K., et al. (2011). Vertical greening systems and the effect on air flow and temperature on the building envelope. *Building and Environment*, 46(11), 2287-2294.

Sanat Mato, U. N. C. C. (n.d.). Biophilic architecture: Balancing visual and thermal strategies for urban spaces. *Biophilic Design Review*.

Tait, R., & Pro, L. (2024). A review of the performance of sustainable microalgae integrated facade projects. *Microalgae Challenges and Advances*, 22(1), 15-33.

Wilkinson, S. J., et al. (2017). Evaluating the thermal performance of retrofitted lightweight green roofs and walls in Sydney and Rio de Janeiro. *Procedia Engineering*, 180, 231-240.

Wilson, E. O. (1984). *Biophilia: The Human Bond with Other Species*. Harvard University Press.

Wilson, J. Q., & Kelling, G. L. (1982). Broken Windows: The police and neighborhood safety. *The Atlantic Monthly*, 249(3), 29-38.

Wong, N. H., et al. (2010). Acoustics evaluation of vertical greenery systems for building walls. *Building and Environment*, 45(2), 411-420.

Yang, Y. (2011). Architecture and nature: Analytical perspective of the Solaris facade. *Contemporary Architectural Studies*, 10(2), 88-102.

Zumthor, P. (2006). *Atmospheres: Architectural Environments - Surrounding Objects*. Birkhäuser.