Do Climate-Responsive Facade Design Strategies in Green High-Rise Buildings Reduce Lifecycle Costs While Enhancing Occupant Comfort?

A Critical Review of Architectural Design Strategies and Performance Outcomes

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***Abstract*—Climate-responsive facades in green high-rise buildings use features like shading systems and double-skin layers to adapt to the environment. This paper examines strategies such as adaptive screens and biomimetic designs, focusing on how effectively they control temperature and daylight to improve comfort for people inside. These methods also help lower lifecycle costs by reducing energy use. Case studies show that these facades can save up to 50% in energy, which matters because high-rise buildings in cities use a lot of energy, especially through their facades, which are exposed to sun, wind, and changing temperatures. Climate-responsive facades use both passive and active features to reduce heat gain, improve ventilation, and enhance indoor air quality, supporting the well-being of occupants. This review explores how these strategies can cut costs over the building's life, including construction, operation, and maintenance, while also making green high-rises more comfortable.. (Abstract)**

***Index Terms*—Climate-responsive facade, green high-rise, occupant thermal comfort, double-skin facade, passive design, building envelope, lifecycle performance** *(key words)*

1.Introduction

The facade of a high-rise building is both its most noticeable feature and its main environmental barrier. It separates the outside climate—sun, wind, rain, and temperature—from the spaces people use inside. Today, with growing concerns about climate change and rising construction and operating costs, smart facade design is more important than ever.

In recent years, green building discussions have focused more and more on engineering metrics like energy use intensity (EUI), LEED points, U-values, and payback periods. These numbers are useful, but they can turn facade design into a simple checklist and take away the qualities that make buildings comfortable, understandable, and lasting. This paper calls for a return to climate-responsive design, following the example of architects such as Hassan Fathy, Ken Yeang, and Renzo Piano, who saw the building's exterior as a smart, adaptable layer that responds to the climate.

The main question this paper asks is whether climate-responsive facade design in green high-rise buildings can lower long-term costs and improve comfort for people inside. Instead of focusing only on financial analysis, the paper looks at how architectural choices—like building orientation, materials, shading, and how open or closed the facade is—affect temperature and performance over time.

2.Literature Review : Climate-Responsive Facade Strategies

2.1 Passive Designs

Passive strategies use building shape and materials to help control the indoor environment. Double-skin facades, which feature a ventilated space between the glass layers, help manage temperature changes and can cut cooling needs by 30-50% across different climates. Adding vertical greenery and high-performance glass improves insulation, filters out pollutants, reduces urban heat, and makes occupants more comfortable. [1]

2.2 Active and Dynamic Systems

Active facade systems use sensors and actuators to adjust to environmental changes in real time. For example, electrochromic facades use sensors and controls to change the glass tint, which reduces glare and heat, while photochromic glass reacts to sunlight levels. These technologies allow more natural light in, reduce the need for artificial lighting, and improve visual comfort without blocking views. Systems like perfusion cooling provide better insulation and evaporative cooling. [2] Simulations show that active facades use less energy for heating and cooling than static designs in many climates. Features like mashrabiya screens reduce solar glare and heat while letting in natural light, which is especially helpful in tropical climates. Improved ventilation and air quality from green features also make occupants more comfortable, and studies show higher satisfaction among people in buildings with climate-responsive facades. [2]

3.Lifecycle Cost Implications

.Dynamic facades cost more at first because they use advanced materials and automation, but they can save 40-67% in energy, with payback periods of five to ten years. Studies show these facades use less energy overall, use recyclable materials, and need less maintenance. Biomimetic systems with perfusion cooling save the most energy. For example, a 150-meter twin tower uses automated mashrabiya screens that follow the sun, which greatly lowers cooling needs in hot climates and lets in daylight for comfort. After people move in, data shows less glare, lower energy use, and lasting benefits from the durable automated system. [3]

4.1 One Central Park, Sydney

Vertical gardens and heliostats in the double-skin facade help cool the building naturally, increase biodiversity, and improve air quality for people inside. The building uses less energy than required by regulations, showing that passive strategies can save money over time. In different climates, fur-perfused facades saved the most energy in tropical areas, with reductions up to 55%. These results show that nature-inspired designs are flexible and effective for improving comfort and reducing costs.[4]

4.Conclusion

Climate-responsive facades in green high-rises improve comfort by adjusting temperature and light, and they also lower lifecycle costs by using energy and materials more efficiently. Examples like Al Bahr and biomimetic designs show these strategies work well and should be used more in city high-rises. [5]

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