International Journal of Social Science Archives

ISSN: 2707-8892

Available at www.ijssa.com

International Journal of Social Science Archives, April - June, 2024, 7(2), 594-602

Sustainable Building Envelopes: A Solution for Energy Crisis in Buildings Pakistan

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***Abstract*:** Pakistan is facing number of challenges due to energy crisis and climate change. The overall economic status is also one of the major factor. The building sector is consuming the resources at faster pace and their products are not environment friendly. The objective of this research was to identify the impacts of the low performance facades that are contributing in the excessive mechanical loads on buildings in addition to a proposal for energy efficient sustainable facades. The façade is one of the major role player as a contributor in the performance of any building typology. The case study approach was adopted through qualitative study to summarize the impacts of low performance façade materials. The results clearly depicted the use of sustainable materials in the exterior would be the solution for the mitigation of future climatic changes.

Key words: Sustainable Buildings, Climate Change, Energy crisis, Smart facades.

1. Introduction

Pakistan faces a multifaceted challenge stemming from its energy crisis and the impacts of climate change (Abbasi & Nawaz, 2020). These challenges are compounded by economic factors, further exacerbating the urgency to address them. Within the built environment, the building sector stands out as a significant contributor to resource consumption and environmental degradation, particularly through the use of non-sustainable materials and inefficient façade designs (Farooqi ET AL., 2005). The building envelope, a vital component of a building, regulates thermal, moisture, and indoor air quality, ensuring its sustainability. Assessing its performance is crucial for reducing resource consumption and environmental degradation. Integrated Performance Models and sustainability assessment methods, such as BREEAM, High Environmental Quality, LEED, and Green Globe, are widely recognized (Pastore & Andersen, 2019).However, there is limited focus on sustainable envelope performance, necessitating a comprehensive approach for regional adaptation. Pakistan's policy and regulatory framework concerning sustainable construction practices and energy efficiency are instrumental in promoting the adoption of sustainable building envelopes(Bhatti & Ghufran, 2020). However, existing policies may lack coherence or enforcement mechanisms, hindering widespread implementation. Strengthening regulatory frameworks, incentivizing sustainable construction practices, and fostering public-private partnerships are essential steps to accelerate the adoption of energy-efficient building envelopes in Pakistan.

1.1 Problem Statement

Pakistan has been facing severe energy crisis since more than two decades and built environment has been a source towards higher demand of energy ever since. It has been observed that lack of climate responsive facade treatment and poor design has been a major contributor to rise in indoor energy demand. Hence there was a dire need to evaluate the end users' perceptions towards these issues and identify the avenues to resolve these gaps for future design of building facades.

2. Review of Literature

New generation skins are evolving to have better responsiveness to environment, better physical material, integrated micro-processors for dynamic automation, wireless sensor and actuators, and design for manufacturing (Jafari & Alipour, 2021). The application of this boundary condition has changed the role of architect in initial building design and development from form to performance, structure to façade(Today, 2015). Enhancement of high-performance buildings tend to prioritize the role of the envelope with new research and developmental measures undertaken. This is because most individuals confront huge alterations on the sustainability front (Selkowitz & Lee, 2004). Concerning performance today, the major approach to designing it is still systems has not altered. To achieve the high level of climatic - optimal for human habitation and survival- Climate needs to be controlled in its natural environment (Aung et al., 2023).

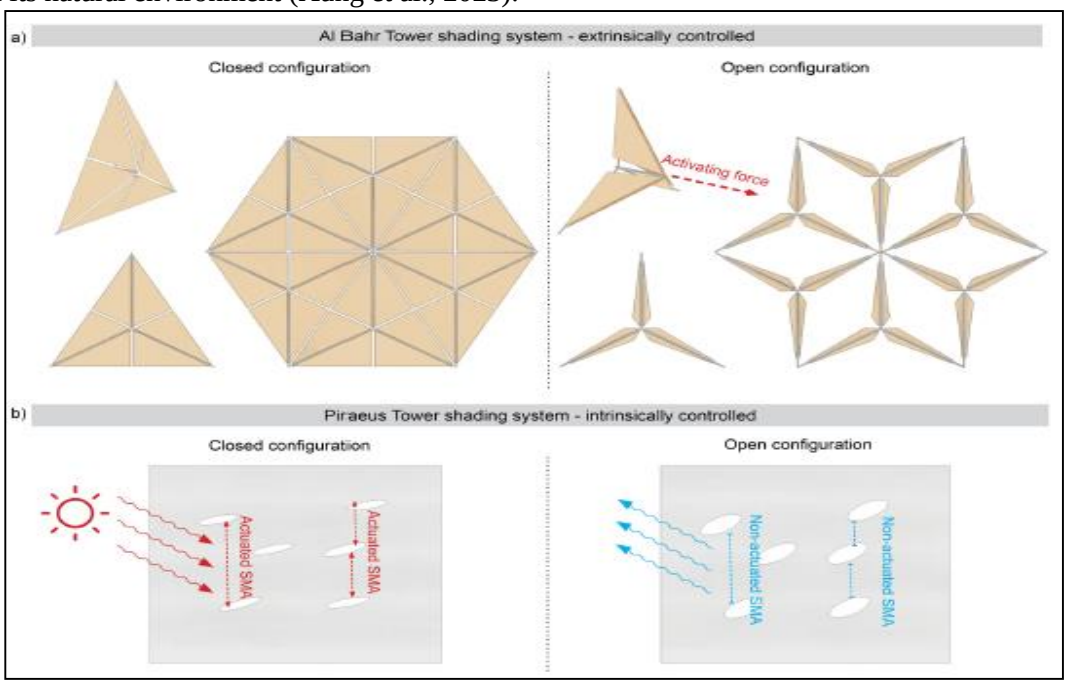


Figure 1 Examples of dynamic shadings: a) extrinsically controlled Al Bahr Tower shading system, b) intrinsically controlled SMA screen of the Piraeus Tower (Carlucci, 2021)

For the modern day world, this paradigm cannot continue as such in response to this challenge. Conventional buildings and their frameworks are built as fixed arrangements while they support components like solar patterns and wind variation with respect to its dynamics (Panopoulos & Papadopoulos, 2017).This, in turn, results in capturing dissociation between the structure and its environment. To reflect this breach, the need for large scale entities like Bosch and Siemens cannot be ignored with respect to the current challenges (Abdelaal et al., 2022). The socio-technical disjunction that exists in this design has led to the appreciation of the Bosch and Siemens entities invention as the solution to the problem. The system should be capable to react on change and incorporate the information into its components and manage their responsive behavior and reactions (Premier, 2019). As a result, the systems are required to respond dynamically: In the case of the customer-facing systems, they have to be able to process the customer requests and demands as and when the customers make them. As a result of alterations taking place in climatic circumstances, the higher the efficiency than the static systems in delivering similar services, the better results it would generate (Sauchelli et al., 2013). A people-centered whole design concept of high-performance green building, which actively pursued passiveness in skin design, has positive impact on improving all building energy as a whole performance, ranging from gigantic buildings to even small scale built forms (Liu et al., 2019).

A high performance covering device or facade that embraces both means of light entrance, namely day lighting, and means of protection against the sun, which is shading (Rashidi et al., 2015).The major innovation of the entire design concept of the building and elements such as the building façade, the kinetic and active shading system along with the natural ventilation systems have the potential to significantly utilize in building operations in an effort to reduce the energy consumed at large (Theodosiou, Tsikaloudaki, Tsoka, & Chastas, 2019). Furthermore, a building skin plays an important role as it becomes part of a building's exterior. With respect to its visual effect and aesthetic, it can also create a source of better value addition on the environment side as well as at the financial side with higher energy saving and better market repute (Taveres-Cachat et al., 2019). Due to the versatility of building the motifs used in the designs are complex and detailed may incorporate more than one style. In order to manage this challenge, numerous operational and visual aspects, can be one of the most significant reasons that can inspire the architects, clients and designers to get succeeded in other stakeholders to make this type of high performance facades and envelopes more successful in deployment as well as in research and exploration (Attoue et al., 2018).

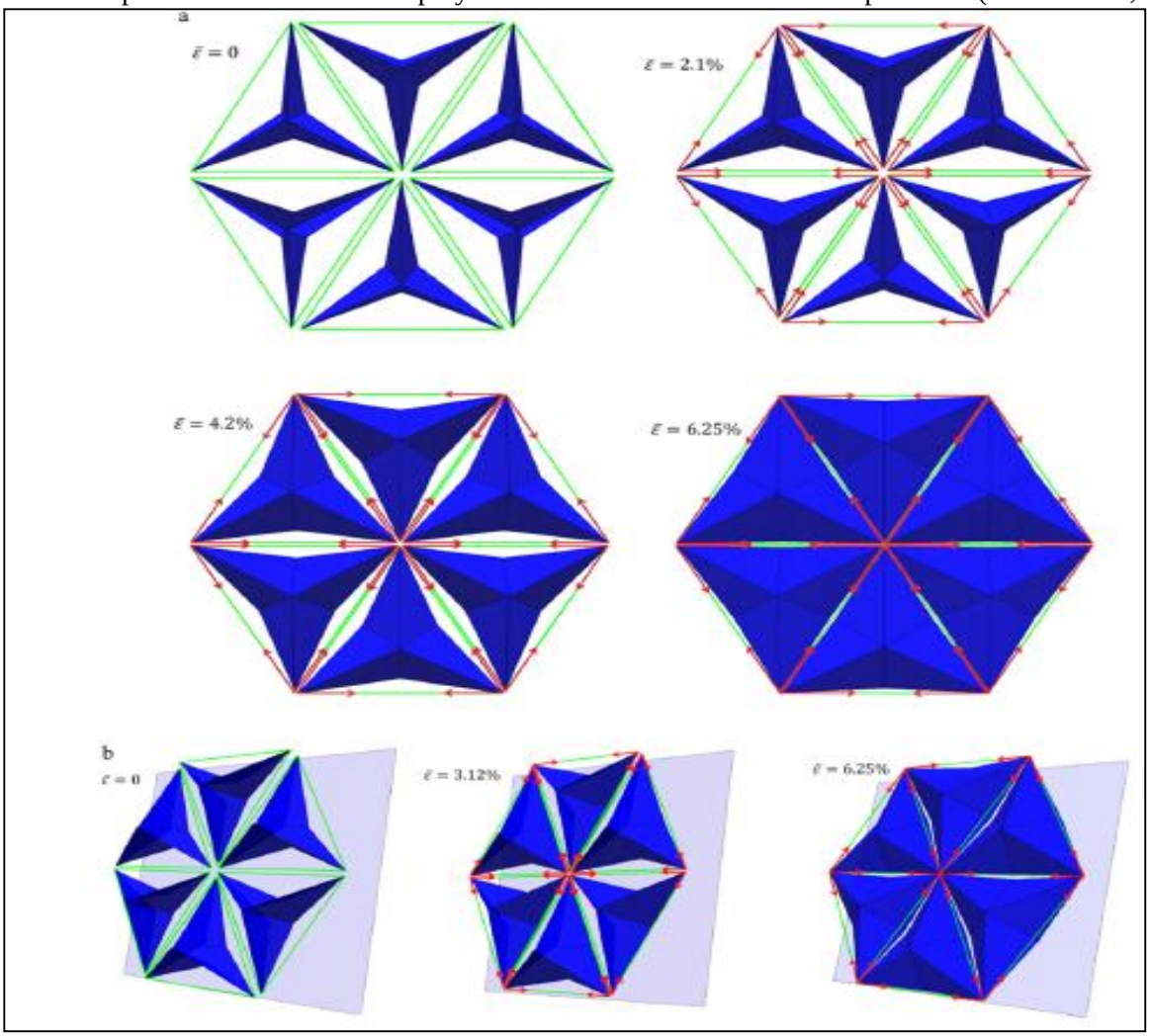


Figure 2 (a) Frontal view of the actuation mechanism of mashrabiya shading screens with tensegrity architecture available at stacks.iop.org/SMS/24/105032/mmedia. (b) 3D view of the actuation mechanism of mashrabiya shading screens with tensegrity architecture (actuation movie provided as supplementary material) (Fraternali et al., 2015)

Concerning about the direct and indirect emissions of the building sector in terms of the greenhouse gases (GHG), the energetic performance has become the subject of intense interest. Since the second half of the twentieth century, the focus on the insulating performance of building envelopes has emerged as efforts are made to achieve minimal connection between the indoor and outdoor environments (Hähn et al., 2021). To the present day, one of the biggest shortcomings of typical constructions is the conflict of inertial response and the dynamic loads acting on them. That means that the modern ability to create responsive buildings which are able to supply numerous improvements in

energy efficiency and comfort inside has recently become faster and more effective due to the spread of innovative technologies, tools, and research (Beevor, 2010).

Computation and automation can claim to take care of the task's intelligence, while the functional aspects of an object depend on material properties and rules about smart. Smart skins allow for more intricate operation than smart envelopes, the latter of which can be fundamentally categorized as either on or off. Skins or covers are intelligent and many of them are designed to operate through the application of external power. Possible features of a building Intelligent Skin include; Intelligent skins may be developed as self-powered and self-actuating surfaces for reducing building energy consumption.

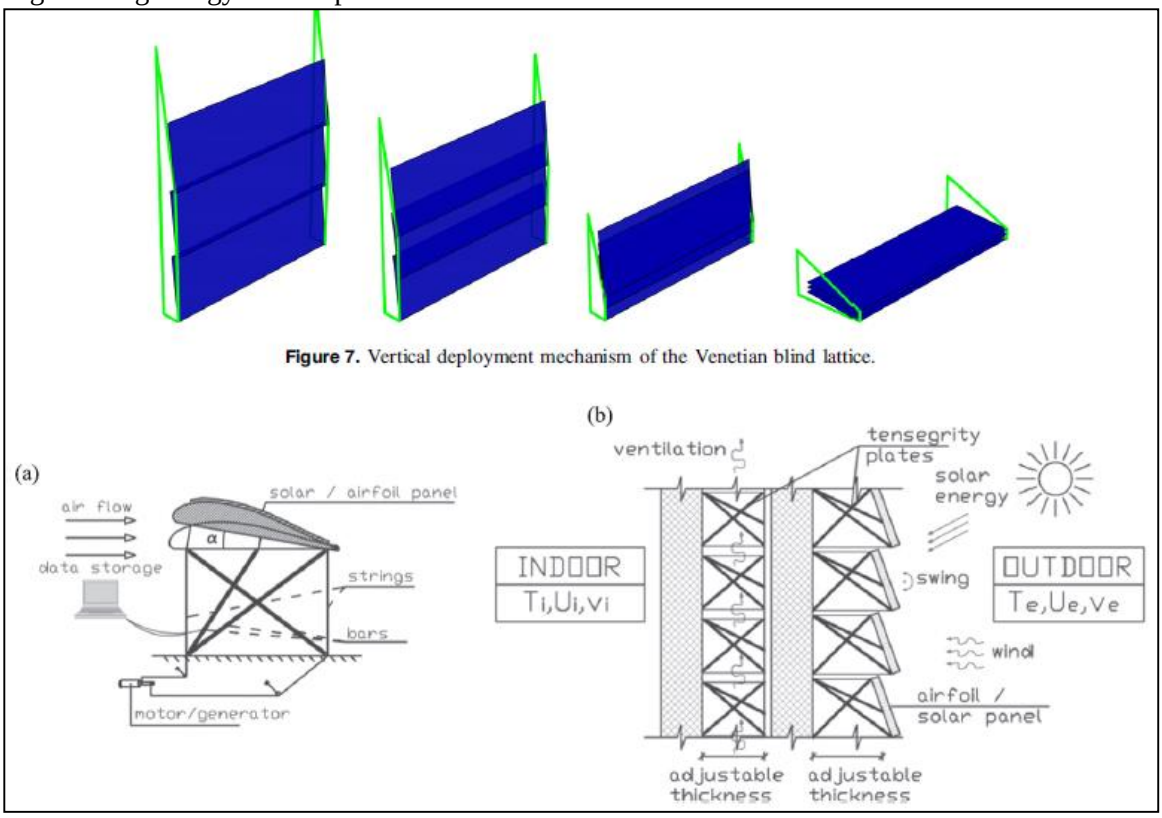


Figure 7. Vertical deployment mechanism of the Venetian blind lattice.

Figure 3 Morphing skins of energy efficient buildings based on tensegrity structures: (a) tensegrity unit; (b) responsive solar façade and ventilated wall (Fraternali et al., 2015).

Thanks to the great interest in energy efficiency and indoor comfort, smart and responsive envelopes have furthered echoed in the research area. The development has eventually led to the aspect of variety of technologies and usage that can enhance energy saving and internal comfort owing to sensitive reaction to the external stimuli with regard to certain parameters (Zhang et al., 2022). World is currently using fossil fuels energy to maintain our interiors at comfortable room temperatures, which accounts for 40-50% of the earth's carbon. Such amount may sound unbelievable, at least if one will try to picture current position on climate change, and drive for shifting to renewable energy sources (Oktafiana et al., 2023). Quite a number of energy saving methods exist and may entail some of the following; efficient use of appliances, insulated walls, effective natural ventilation, heat and Warm water pumps, thermal storage, smart solar shading, among others (Sommese et al., 2023).

3. Research Methodology

In order to continue forward, the overall research process focused on developing a research approach to help identify how the forward line of action based on review of literature could be evolved. Hence research methodology was developed based on case study method evolved through observational study and data collection about the site and building details under exploration. Local buildings based approach was adopted to ensure that real data could help from the ongoing sites with issues to help manage these areas identification, documentation and later their analysis may be used for reporting these gaps.

4. Case Study

4.1 Sapphire Residence Tower

Sapphire Residence Tower, built between 2006 and 2010, its Turkey's tallest residential building with a 261-meter height. Climate, architectural space, and mechanical system data are summarized under three groups. The building's structural components consist of a reinforced concrete shear wall frame and an envelope structure of two independent layers. Zone separation is applied to reduce the number of zones in high-rise buildings. The Design Builder building model was created with zone separation in mind, and the "ASHRAE 62.1 Ventilation for Acceptable Indoor Air Quality" standard was defined among the zones.

The building's energy consumption calculations were made for the residential tower, and the building envelope properties were defined on the respective façade surfaces.

Table 1: Climatic Data

CLIMATE DATA	**Location**	4.Levent Istanbul-Turkey
	Coordinate	41’5’6.28”NORTH 29”0”21.96”EAST
	Altitude	124m
	Heating degree days zone	2nd HDD (INTERNATIONALY 2700 HDD

Table 2: Architectural Style Details

ARCHITECTURAL DATA	**SPACE**	Total building floor area	59.744m²
		Total building volume	250.580m3
		Area volume ratio A/V	0,24
		Heat-loss surface area by direction	North&South7.260m2 East & West 11.880m2
		Total façade area	38.280m2
		Façade transparency ratio	%71

Table 3: Transparency Ratio of Building Envelope

FACADE	**SURFACE AREA**		**TRANSPERANCY RATIO**
	Transparent	**Opaque**	
North-South	3.350m2	3.910m2	%46
East- West	10.295m2	1.585m2	%87
Total	27.290m2	10.990m2	%71

Table 4: Thermophysical Properties of the Envelope

FACADE		**PROPERTIES**		
		Façade component	**Thickness**	**Total U-value**
OPAQUE WALL	CURTAIN	Gypsum plaster	20mm	0.20Wm2 K
		Reinforced Shear Wall	800mm	
		Rock wool insulation	80mm	
		Air Gap	100mm	
		Enameled painted glass (6mm+1.5mm+10mm)	17.5mm	
GLASS WALL	CURTAIN	Glass (with 0.691SHGC)		1.10W/m2K
		Metal façade system		2.00W/m2K

profile

4.2 Barkat Market Lahore

The Barkat Market in Lahore's central hub is surrounded by numerous multistory buildings, but their facades are poorly maintained, with no proper ventilation. Billboards block ventilation for both residential and commercial buildings. Figures depict the condition of facades and chaos in this area.

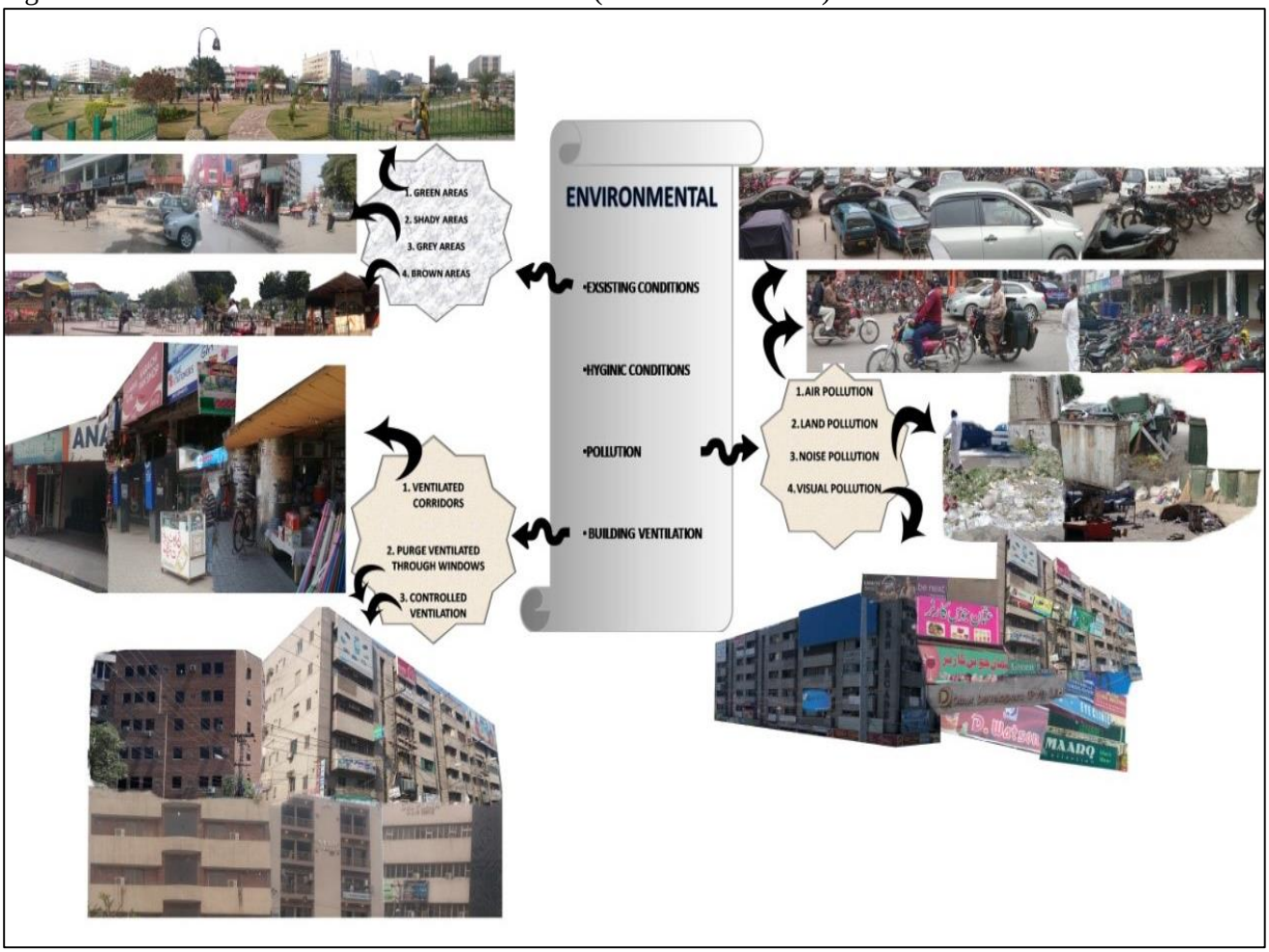
Figure 04 Live pictures of the market corridor as captured by researcher

Figure 05 Montage designed to paint a true picture of the existing conditions on site (Source: Researcher)

Table 5: Issues of Barkat Market

ISSUES OF BARKAT MARKET	Ventilation issues No Natural light Compromised aesthetics Randomly placed Billboard and signage Inefficient use of materials in facades constriction can cause high energy consumption and contributing to environmental issues

Figure 6: Environmental Concerns Observed at Site (Source: Researcher)



Barkat Market's façade is often perceived as dull and unattractive, which is crucial for attracting the public. To improve its appeal, the research suggests that there is a need of Sustainable facades that provide energy security, environmental sustainability, and economic resilience. However, achieving their full potential requires policymakers, industry stakeholders, and the community to overcome challenges and capitalize on emerging opportunities. This approach will enhance the market's overall appeal and appeal to the public. The case studies showed that high-rise buildings offer standard residential comfort while promoting energy efficiency. High-rise buildings with residential functions have a 50% higher impact on façade costs compared to office buildings. Buildings with double-layered or air corridor façades have higher heating and cooling energy efficiency, resulting in increased indoor comfort and reduced energy loads. This highlights the importance of energy-efficient design in Turkey for sustainable development and the use of Building Information Modeling (BIM) in construction. However, in Pakistan, embracing sustainable building envelopes is crucial for addressing energy challenges. Collaboration between *policymakers, industry stakeholders, and the community* can accelerate the adoption of sustainable construction practices and create a more sustainable and resilient built environment for future generations.

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5. Conclusion

Sustainable building envelopes represent a promising solution for addressing Pakistan's energy crisis and environmental challenges. By mitigating energy consumption and enhancing building performance, sustainable facades offer a pathway towards achieving energy security, environmental sustainability, and economic resilience. Research purposed that all future construction must be stimulating and keeping them as a baseline future construction is made. However, realizing the full potential of sustainable building envelopes requires concerted efforts from policymakers, industry stakeholders, and the broader community to overcome existing challenges and

capitalize on emerging opportunities.

5.1 Future Directions

Emerging technologies and trends hold promise for advancing sustainable building envelope solutions in Pakistan. Innovations in materials science, construction techniques, and renewable energy integration offer opportunities to enhance the performance and affordability of sustainable facades. Embracing these advancements can drive progress towards achieving energy security, environmental sustainability, and economic prosperity in Pakistan's built environment. Despite the potential benefits, several challenges and limitations impede the widespread adoption of sustainable building envelopes in Pakistan. Cost barriers, limited awareness, and cultural preferences for traditional construction methods pose significant obstacles. Moreover, inadequate technical capacity and supply chain constraints hinder the availability and affordability of sustainable materials and technologies.

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