

Comparative Analysis of Louver and External Shading Systems for Energy Efficiency in Low-Income Housing

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Abstract - This study presents a comparative analysis of louver shading systems and external shading systems as passive design strategies for enhancing energy performance in low-income group buildings under varying climatic conditions. With growing emphasis on sustainable architecture and energy conservation, especially in economically constrained communities, shading systems offer a cost-effective solution for improving thermal comfort, reducing solar heat gain, and minimizing dependence on mechanical cooling. Louver shading systems—comprising horizontal, vertical, or diagonal slats—are orientation-specific and can reduce solar heat gain by approximately 55%, offering flexibility through adjustable configurations and low maintenance requirements. External shading systems, such as overhangs, vertical fins, and perforated screens, provide broader façade coverage and greater thermal performance, with heat gain reductions reaching up to 65%. These systems also enhance visual comfort and ventilation while contributing aesthetically to building design. Through a qualitative and data-driven comparison across key performance indicators—including shading effectiveness, cost, retrofitting adaptability, and ventilation potential—this research highlights the strengths and limitations of each system. The findings underscore the importance of contextual and climatic considerations in the selection and implementation of shading solutions, particularly in low-income housing, where affordability and energy resilience are critical. By leveraging appropriate shading strategies, architects and urban planners can significantly improve building performance and occupant well-being, contributing to more sustainable and inclusive urban environments.

Key word: Methane micro-combustor, micro-combustion, portable power generation.

Introduction

The global focus on sustainable and energy-efficient building design has intensified due to rapid urbanization, climate change, and increasing energy poverty. In developing countries, low-income populations often inhabit poorly insulated buildings with limited access to mechanical cooling or efficient lighting. This exacerbates energy vulnerability, particularly in regions experiencing extreme heat or fluctuating climates. One of the most accessible and effective passive solutions to address this challenge is the use of louver shading systems, which regulate solar radiation,

enhance daylight penetration, and reduce dependence on artificial cooling and lighting systems [1].

Louvers are architectural elements consisting of inclined or horizontal slats, traditionally fixed or operable, that allow air and light to pass through while blocking direct sunlight and rain [2]. Widely used across cultures and climates for centuries, modern louver systems have evolved in design and function—from simple wooden slats in tropical vernacular homes to sophisticated, sensor-controlled devices in contemporary facades. The appeal of louver systems lies in their dual ability to reduce thermal gains during peak solar hours and to enhance visual comfort by diffusing daylight [3].

Studies show that external shading systems, such as louvers, can reduce solar heat gain by up to 80%, depending on orientation, material, and design configuration [4]. Unlike internal blinds, external louvers intercept solar radiation before it enters the building envelope, thus significantly reducing cooling loads. In warm and tropical climates—where air conditioning is either unavailable or unaffordable—this reduction has profound implications for occupant comfort and health [5]. Furthermore, in naturally ventilated buildings, shading devices assist in maintaining acceptable indoor air temperatures by mitigating the heat island effect and solar-induced indoor heating [6].

Beyond thermal control, daylighting optimization is another crucial benefit of louver systems. By controlling the angle and spacing of slats, designers can allow diffused light to penetrate deeper into interior spaces without causing glare or overheating. This passive lighting strategy contributes to substantial energy savings—typically between 20% and 60% of lighting electricity consumption—while improving occupant well-being and productivity [7]. Hybrid systems that combine vertical and horizontal louvers or dynamic louvers that adjust based on solar angle have been shown to improve daylight autonomy and reduce reliance on electric lighting in diverse climates [8].

In a comparative simulation study across five cities (Miami, San Diego, Melbourne, Guangzhou, and Milan), a hybrid triangular-horizontal louver system reduced Energy Use Intensity (EUI) by up to 50% while achieving UDI (Useful Daylight Illuminance) and DA (Daylight Autonomy) values over 80%, outperforming traditional fixed systems [9]. Similarly, in classroom environments in Egypt, vertical

external louvers reduced annual cooling energy by 49% and lighting consumption by 27% [10]. These figures highlight the potential of well-designed louvers not only for commercial or institutional buildings but also for residential sectors, especially in regions with high solar exposure.

However, in the context of low-income housing, the application of louver shading systems remains underrepresented in academic literature and policy implementation. Many studies prioritize commercial or experimental buildings with advanced control systems, overlooking the constraints—such as cost, maintenance, and construction simplicity—faced by low-income communities [11]. In these contexts, fixed or semi-fixed louvers, made from low-cost materials like timber, aluminum, or recycled plastics, offer practical solutions. These designs are low-maintenance, durable, and effective when tailored to building orientation and local climate [12].

Design parameters—such as louver angle, slat width, spacing, and reflectivity—play critical roles in determining shading efficiency. For example, a study in Iran demonstrated that louver angles of -20° on south-facing facades minimized lighting energy to just 6.2 kWh/m^2 , whereas larger positive angles significantly increased consumption [13]. Moreover, the orientation of louvers affects both shading and lighting: horizontal louvers are more effective on north and south facades in the northern hemisphere, while vertical or egg-crate systems perform better on east and west facades [14].

Another emerging concept is the integration of Photovoltaic (PV) panels into louver systems, combining energy generation with shading. These PV-integrated shading devices (PVIS) not only reduce indoor cooling demand but also produce electricity—an attractive proposition for off-grid or low-income homes in sun-rich regions. One study in Riyadh, Saudi Arabia, showed that PV louvers could reduce total energy use by 18–24% and achieve a return on investment in under 10 years, depending on configuration [15].

Despite the promising potential of louver systems for improving thermal comfort and reducing energy bills, implementation in low-income buildings is hindered by several challenges. These include lack of awareness, absence of local design guidelines, insufficient climatic data for precise optimization, and policy inattention to passive design strategies. Additionally, many simulation studies do not translate into real-world retrofits, and few field studies examine actual thermal performance in low-cost housing.

To bridge this knowledge and application gap, a comprehensive understanding of louver energy performance under diverse climatic conditions is essential—especially when applied to the low-income residential sector, where energy resilience is most needed. This review aims to

critically examine how louver shading systems perform across varied climates, focusing on:

- Energy savings (cooling, lighting, and total energy use)
- Daylighting quality and glare control
- Thermal comfort improvements
- Cost-effectiveness for low-income housing
- Climate-responsive design adaptations

We organize our analysis by climate zone (hot-arid, hot-humid, temperate, and mixed), and by louver type (fixed, dynamic, hybrid, PV-integrated), with specific emphasis on systems suitable for low-cost, low-maintenance deployment. By consolidating empirical and simulated findings, we aim to guide future research, design practices, and policy interventions that leverage louvers as accessible, passive, and sustainable solutions for enhancing comfort and reducing energy burdens in marginalized communities.

2. Louver shading systems

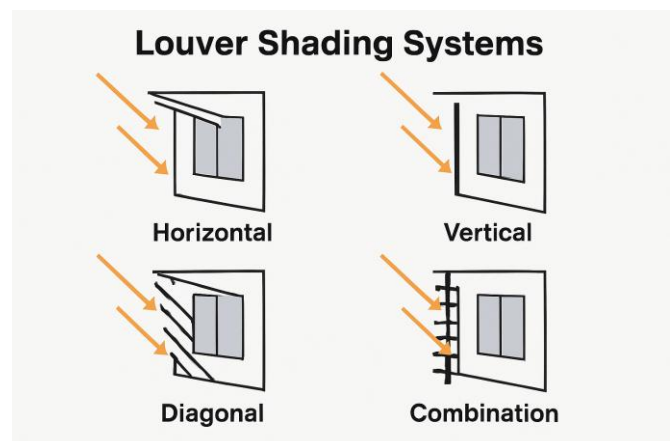


Figure 1. Louver shading systems

Figure 1. Louver shading systems are architectural elements designed to control the amount of sunlight entering a building, thereby reducing solar heat gain, glare, and dependence on artificial cooling and lighting. These systems consist of slats—typically fixed or adjustable—arranged in specific orientations to block or redirect sunlight, making them a highly effective passive design strategy. They are particularly beneficial in low-income housing, where mechanical cooling systems are often unaffordable or unavailable. The effectiveness of a louver system depends on several factors, including its orientation, material, angle, and location. The image provided illustrates four major configurations: horizontal, vertical, diagonal, and combination louvers—each suited to different climatic conditions and façade orientations.

Horizontal louvers are installed above windows and are most effective in blocking high-angle sunlight, particularly from the south in the northern hemisphere. They are ideal for hot climates where protection from midday sun is essential. By preventing direct sunlight from entering during peak hours while still allowing indirect light, horizontal louvers significantly reduce indoor heat gain and improve comfort. Their simple design, cost-effectiveness, and minimal maintenance requirements make them especially suited to low-income residential projects.

Vertical louvers, on the other hand, are positioned on the sides of windows and are most useful on east and west-facing walls. These orientations receive low-angle sunlight during morning and evening hours, which is difficult to shade using horizontal systems. Vertical louvers help block this sunlight, reducing both glare and overheating. They also provide privacy without sacrificing ventilation and can be fixed or operable depending on user preference and budget constraints.

Diagonal louvers represent a hybrid approach, combining attributes of both horizontal and vertical shading. Installed at an angle across the window plane, diagonal louvers offer more comprehensive shading coverage, especially in regions where solar angles vary throughout the day. Their slanted configuration can effectively reduce glare while allowing daylight penetration, depending on their tilt and spacing. Though slightly more complex to design and install, they offer a strong balance between functionality and aesthetics.

The combination louver system integrates multiple orientations—usually horizontal and vertical—to create a versatile solution for buildings with diverse exposure. These systems provide excellent shading performance regardless of sun position and are ideal for structures on corner plots or with multiple façade orientations. Although more intricate and potentially costlier to install, combination louvers offer superior control over daylight and thermal conditions, particularly when designed with climate responsiveness in mind.

In the context of energy efficiency and occupant comfort, louver systems stand out as one of the most impactful passive design strategies. For low-income buildings, where energy resilience is crucial and budgets are limited, louvers offer a practical solution that balances affordability with performance. Constructed from locally available materials such as wood, metal, or recycled composites, these systems can be tailored to site-specific needs and integrated into both new constructions and retrofitting projects. As climate change continues to intensify the frequency and duration of heatwaves, especially in urban environments, the adoption of effective shading systems like louvers becomes not only beneficial but essential for sustainable, inclusive housing development.

3. External shading systems

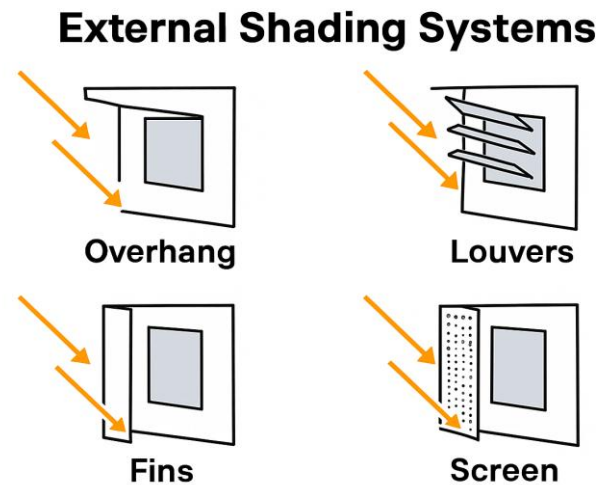


Figure 2. External shading systems

Figure 2 External shading systems are passive design strategies used to control solar radiation before it penetrates building interiors, thus reducing cooling loads and enhancing occupant comfort. The image provided showcases four common external shading types: overhangs, louvers, fins, and screens. Each system has unique characteristics tailored to specific climatic and architectural needs.

Overhangs are horizontal projections installed above windows or openings. They are highly effective in blocking high-angle midday sun, especially on south-facing facades in the northern hemisphere. By preventing direct sunlight during peak hours while allowing diffused daylight, overhangs help minimize internal heat gain and glare. Their design is simple, cost-effective, and often integrated into the building's structural or aesthetic elements.

Louvers, shown here as multiple slats set at an angle, offer more dynamic shading. They can be horizontal, vertical, or diagonal, and are often adjustable to respond to seasonal or daily changes in solar angles. Louvers balance shading and daylighting, making them especially valuable in buildings aiming for energy efficiency. They are commonly made from metal, wood, or composite materials.

Fins are vertical elements placed on the sides of windows, particularly effective on east- and west-facing façades. These orientations experience low-angle sunlight in the mornings and evenings, which is difficult to block using overhangs. Fins provide consistent shading without obstructing airflow or natural light, and they also enhance façade articulation.

Screens, often made from perforated or mesh materials, filter sunlight while maintaining visibility and ventilation. They are highly customizable and can serve both aesthetic and functional purposes. Screens are especially useful in hot

climates, where they reduce heat and glare while preserving exterior views.

Table 1. Compare between Louver Shading Systems and External Shading Systems

Criteria	Louver Shading Systems	External Shading Systems
Shading Effectiveness	High (Orientation-specific)	Very High (Full façade coverage)
Solar Heat Gain Reduction (%)	55%	65%
Glare Control	Moderate to High	High
Cost (Low/Medium/High)	Medium	Low to Medium
Aesthetic Flexibility	Moderate	High
Material Variety	Wood, Plastic	Metal, Metal, Composite, Fabric
Suitability for Retrofitting	Good	Excellent
Maintenance Requirements	Low	Medium
Ventilation Enhancement	Good	Very Good
Sunlight Adjustability Control	Yes (if adjustable)	Depends on type

Table1 shows Louver shading systems and external shading systems are two essential passive architectural strategies aimed at improving energy efficiency and thermal comfort in buildings. While both systems serve the primary function of controlling solar radiation and reducing internal heat gain, their effectiveness, design characteristics, and suitability for various applications differ significantly.

Louver shading systems consist of horizontal, vertical, or diagonal slats positioned to block direct sunlight while allowing natural daylight and ventilation. These systems are particularly effective when oriented correctly according to the building’s facade, offering solar heat gain reduction of up to 55%. Louvers are often made of wood, metal, or plastic and are suitable for retrofitting due to their modularity and relatively simple installation. They also require minimal maintenance and can be fixed or adjustable, providing flexibility in sunlight control. However, their aesthetic flexibility is moderate, and they are most effective when carefully tailored to specific sun paths.

On the other hand, external shading systems—such as overhangs, vertical fins, and perforated screens—offer broader shading coverage and often achieve higher performance in terms of heat reduction, with solar gain reductions around 65%. These systems can cover entire facades and are particularly effective in climates with intense sunlight or in multi-story buildings. External shading devices are highly adaptable in design and materials, ranging from metal to composite and fabric solutions. They enhance both the thermal and visual comfort of interior spaces by controlling glare, allowing filtered daylight, and promoting ventilation. Although slightly more complex and cost-sensitive in terms of design and installation, they provide excellent retrofit potential and aesthetic value.

In summary, louver shading systems are highly effective and economical for targeted shading, while external shading systems offer comprehensive solar protection and design flexibility. Both play a vital role in sustainable architecture, especially in low-income housing, where passive solutions are key to maintaining comfort without high energy costs.

Table 2. Compare

Performance Criteria	Louver Shading Systems	External Shading Systems
Energy Savings (Cooling)	Moderate (30–50%)	High (40–60%)
Energy Savings (Lighting)	Moderate	High
Total Energy Use Reduction	Up to 40%	Up to 55%
Daylighting Quality	Good (orientation-based)	Excellent (broad coverage)
Glare Control	Moderate	High
Thermal Comfort Improvements	Improves comfort in targeted zones	Provides uniform thermal comfort
Cost-Effectiveness for Low-Income Housing	High (affordable and low-maintenance)	Moderate to High (depends on materials and design)
Climate-Responsive Design Adaptations	Customizable by façade orientation	Versatile across climates and façades

Louver and external shading systems both improve building energy performance, but their effectiveness varies by application. Louvers offer moderate cooling and lighting energy savings, are affordable, and work best when tailored to façade orientation. They are ideal for low-income housing due to low cost and easy retrofitting. In contrast, external shading systems provide higher overall energy savings,

better glare control, and uniform thermal comfort, especially in diverse climates. Though sometimes more expensive, they offer greater daylighting quality and flexibility across building types. Choosing the right system depends on climate, budget, and the need for thermal and visual comfort.

4. Conclusion

In conclusion, both louver shading systems and external shading systems play a crucial role in enhancing energy efficiency, thermal comfort, and daylight management in low-income group buildings. Louvers offer targeted solar control with moderate cost, low maintenance, and adaptability to various façade orientations, making them suitable for simple and effective shading in hot climates. External shading systems, on the other hand, provide more comprehensive solar protection, improved ventilation, and aesthetic flexibility, particularly beneficial for buildings exposed to high solar loads or complex orientations. While external systems may involve higher initial costs, their long-term performance benefits often outweigh the investment, especially in retrofitting scenarios. Selecting the appropriate shading strategy requires consideration of local climate, building orientation, material availability, and user needs. By integrating these passive solutions thoughtfully, stakeholders can significantly reduce energy consumption, enhance indoor environmental quality, and promote sustainability in economically constrained housing, ultimately supporting climate-responsive and socially equitable architecture.

References

1. Misawa, Y. et al. (2022). Performance Assessment of Shading Louvers in Office Buildings. *Journal of Facade Design and Engineering*.
2. Wikipedia. (2024). Louver. Retrieved from <https://en.wikipedia.org/wiki/Louver>
3. Asuzac ACM. (2023). Sun Shading Louvers: Enhance Comfort and Efficiency.
4. Omar, H. et al. (2020). Optimizing Shading Devices in Cairo's Schools. *Sustainability*, 12(5), 2178.
5. Azadeh, A. et al. (2016). Solar Control Strategies for Hot Climates. *Renewable Energy*, 93, 120–132.
6. Kim, Y., & Park, C. (2023). Thermal Performance of Louvers in Korean Office Buildings. *Buildings*, 13(5), 1209.
7. Mahdavinejad, M. et al. (2021). Daylight and Energy Simulation in Arid Climates. *Journal of Building Performance*, 12(2), 45–57.
8. Mehrabian, M. et al. (2020). Effects of External Louvers on Solar Heat Gain. *Building Simulation*, 13(4), 785–794.
9. Zhao, X. et al. (2024). Hybrid Louver Façade Design for Daylight and Energy. *Energy Reports*, 10, 451–468.
10. Elmahdy, A. et al. (2019). Passive Cooling in Egyptian Schools. *Building and Environment*, 148, 137–150.
11. Hashim, H. et al. (2020). Barriers to Energy Efficiency in Low-Income Housing. *Energy Policy*, 142, 111556.
12. Rahman, A. et al. (2021). Cost-Effective Shading Devices in Tropical Urban Housing. *Sustainability*, 13(7), 4021.
13. Amiri, H., & Rezaei, M. (2020). Optimizing Louver Angles for Lighting Efficiency. *Journal of Energy and Buildings*, 225, 110324.
14. Gonzalez, F. et al. (2018). Orientation-Specific Louvers and Cooling Loads. *Solar Energy*, 174, 332–343.
15. Alshahrani, S. et al. (2022). Economic Assessment of PV Louver Façades in Riyadh. *Buildings*, 15(2), 222.