Material Science and Engineering International Research Journal
ISSN: 2997-6685|
Volume 12 Issue 3, July-September, 2024
Journal Homepage: https://ethanpublication.com/articles/index.php/E30
Official Journal of Ethan Publication

OPTIMIZING DOUBLE SKIN FAÇADE GLAZING FOR ENERGY EFFICIENCY IN SHOPPING MALL DESIGN: A CASE STUDY OF JAHI, ABUJA

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DOI: https://doi.org/10.5281/zenodo.17190396

Abstract
This study evaluates the effectiveness of double skin façade (DSF) glazing systems in improving energy efficiency in shopping mall buildings within Abuja's hot-humid climate. Using building performance simulations, the energy demands of various glazing configurations thermochromic, low-emissivity (low-E), tinted, and clear glass in single, double, and triple panes were compared against a base case model without DSF. Results reveal that thermochromic glazing and low-E double-pane glass achieved the greatest reductions in annual cooling energy demand, lowering consumption by up to 14% compared to conventional façades. Conversely, single-pane and untreated clear glazing exhibited the poorest performance. The study demonstrates that DSF systems optimized with climate-specific glazing significantly enhance thermal regulation, reduce cooling loads, and support sustainable commercial architecture in Nigeria.

Keywords: *Double skin façade, Energy efficiency, Glazing strategies, Hot-Humid climate and Shopping mall*

1.0 INTRODUCTION

Scientists have declared that energy efficiency has become a critical global issue due to increasing concerns over climate change, resource depletion, and rising energy costs. In Nigeria, the demand for energy continues to grow, driven by rapid urbanization, population growth, and economic development (United States Environmental Protection Agency, 2023). As posited by Adewolu (2023), the country faces significant challenges in meeting its energy needs, with much of its electricity generation relying on non-renewable resources, leading to environmental degradation and high carbon emissions. This situation underscores the urgent need for innovative building strategies that can reduce energy consumption and enhance sustainability.

Commercial buildings such as shopping malls are among the most energy-intensive building types due to their large cooling requirements, particularly in hot-humid climates. In Abuja, Nigeria, where high solar radiation and prolonged warm seasons prevail, façade systems play a critical role in determining building energy performance. The rapid expansion of shopping malls in Abuja, especially in areas such as Jahi District, reflects both socio-economic transformation and increasing urban energy demand. These climatic and urbanization pressures call for rethinking façade design strategies to minimize cooling energy demand while ensuring occupant comfort.

Double Skin Façade (DSF) systems have emerged as innovative passive design solutions capable of enhancing insulation, daylight control, and thermal comfort, thereby reducing reliance on mechanical cooling systems (Abubakar & Ibrahim, 2019). Globally, DSFs are increasingly adopted in high-profile buildings designed by renowned architects and engineers, often celebrated as exemplary "green" building strategies. DSF is defined as a pair of glass skins separated by an air corridor, where the main layer of glass is usually insulating. The cavity acts as a buffer against wind, sound, and temperature variations, with shading devices often placed inside to regulate solar gain (Schmid et al. 2019; Bello, 2021). Depending on design intent, the glass skins can be single or double glazing units with cavity depths ranging from 20 cm to 2 m, making them versatile in optimizing façade performance.

While DSFs have been widely studied and implemented in Europe, Asia, and North America, their potential in sub-Saharan Africa remains underexplored. Specifically, empirical research on DSF applications in Nigeria is scarce, and little is known about their performance in hot-humid composite climates like Abuja. Moreover, while façade optimization strategies such as thermochromic and low-emissivity (low-E) glazing have shown promising results in temperate regions, their adaptability and effectiveness in Nigeria's climatic conditions require critical evaluation.

Against this backdrop, this study evaluates the effectiveness of DSF glazing systems in enhancing energy efficiency in shopping mall buildings within Abuja's hot-humid climate. The specific objectives are to: (1) analyze the annual energy demand of shopping mall buildings in Abuja's composite climate; (2) compare the performance of various glazing and cavity configurations of DSFs in reducing cooling energy demand; (3) determine the most energyefficient glazing option and cavity depth combination for Abuja's climatic conditions; and (4) demonstrate the extent of energy savings achievable by integrating the optimal glazing configuration into shopping mall design.

By localizing global façade optimization strategies to the Abuja context, this study contributes to both academic discourse and practical knowledge on sustainable building envelopes. It also aligns with the United Nations Sustainable Development Goals (SDGs) on affordable and clean energy (SDG 7), sustainable cities and communities (SDG 11), and climate action (SDG 13), thereby emphasizing its broader environmental and socio-economic relevance.

1.1 STATEMENT OF THE PROBLEM

In Abuja's hot-humid climate, shopping malls experience high cooling loads due to extensive glazing surfaces and poor façade designs, leading to excessive energy consumption and operational costs. Current design practices often neglect climate-responsive façade strategies, resulting in unsustainable building performance.

2.0 LITERATURE REVIEW

2.1 Double Skin Facade (DSF)

A double skin façade (DSF) consists of two layers typically a glazed outer skin and a glazed or mixed inner skin separated by a ventilated cavity that dissipates heat through natural or mechanical airflow. The cavity, usually 20 cm to 2 m wide, may also contain solar shading devices to reduce radiation. Beyond aesthetics, DSFs improve building performance by enhancing comfort, reducing external noise and wind loads, and lowering energy demand (Abubakar et al. 2019). Widely applied in cold and moderate climates, they support thermal regulation, daylighting, natural ventilation, and acoustic control. Recent studies highlight the usefulness of airflow network models and computational fluid dynamics (CFD) simulations in optimizing DSF performance analysis (Abubakar et al. 2019).

2.2 Benefits of Double Skin Facade (DSF)

Scholars such as Abubakar et al. (2019), Schmid et al. (2019), and Zin et al. (2020) have highlighted several performance-enhancing benefits of double skin façades (DSFs), including:

1. Natural ventilation is facilitated through the cavity, as the external skin provides protection, enabling airflow without compromising occupant comfort even under harsh climatic conditions such as wind, rain, or snow.
2. Reduced energy consumption is achieved by limiting solar heat gain through the façade, thereby lowering the building's cooling load.
3. Occupant comfort and productivity are enhanced as users can regulate light penetration with louvers or shading devices and control air movement and temperature through operable windows, thereby improving environmental quality and overall work performance.

2.3 Components of Double Skin Façades

A double skin façade (DSF) system comprises key components that collectively enhance its functionality and energy efficiency. It typically consists of an inner and outer glass layer separated by a ventilated cavity, which serves as the intermediate space. Within this cavity, adjustable shading devices and openings are integrated to regulate solar gain and airflow (Zin et al. 2020). In essence, the DSF functions as a façade system equipped with an air cavity between two glazing layers, complemented by shading devices and ventilation features. **i. Cavity**

The cavity between inner and outer glazing is the defining feature of a double skin façade (DSF), influencing ventilation, solar control, and insulation (Zin et al. 2020). Properly designed cavities enhance energy efficiency by reducing heat gain and noise while protecting against adverse microclimatic effects. However, poor design can increase cooling loads, making cavity depth a critical factor. Research suggests effective depths range between 20 cm and 200 cm, with narrower cavities often performing better depending on climate and building needs (Zin et al. 2020).

Table 1: Performance Impact of Different Cavity Depths in Double Skin Façade (DSF) Design

Cavity Depth Range	Performance Impact
< 20 cm	Too narrow, limits ventilation effectiveness
20–50 cm	Efficient for ventilation and solar control in hot climates
50–100 cm	Balanced performance, widely used in DSF design

100–200 cm	Provides good insulation, but may risk overheating if poorly ventilated
> 200 cm	Too wide, reduced efficiency and higher construction cost

Source: Adapted from Zin et al. (2020); Belgium Building Research Institute.

ii. Inner and Outer Skin Glaze Façade

Glazed façades are increasingly used in office buildings but strongly affect energy performance. A double skin façade (DSF) combines inner and outer glazing with a cavity and shading devices to improve comfort and reduce cooling demand (Zin et al. 2020). In ventilated systems, insulated glazing is often placed externally while the inner layer provides enclosure and maintenance access. The choice of glass type and thickness is crucial, as it influences cooling load, daylighting, acoustic comfort, and overall DSF efficiency.

iii. Shading devices

Solar shading is widely recognized as a cost-effective passive cooling strategy, particularly in developing countries (Yahuza et al. 2019). Within a double skin façade (DSF), shading devices work in conjunction with the cavity and glazing layers to improve thermal comfort and reduce energy use (Alwetaishi et al. 2021; Zin et al. 2020). Their effectiveness depends on site context, design objectives, and climate, making early design integration crucial. Properly coordinated with the cavity, shading devices enhance façade performance and overall building energy efficiency.

2.4 Theoretical Framework

This study is anchored on **Sustainable Architecture Theory** and **Building Performance Theory,** both of which provide the conceptual foundation for evaluating double skin façade (DSF) systems in enhancing energy efficiency.

2.4.1 Sustainable Architecture Theory

This theory emphasizes the integration of environmentally responsive design strategies that reduce ecological footprints while promoting occupant well-being (Kibert, 2016). In the context of DSFs, this theory underscores the need to balance energy efficiency with indoor environmental quality through climate-responsive building envelopes. The theory aligns strongly with the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action), by advancing energy-efficient architectural practices that mitigate carbon emissions and support resilient urban growth (UN, 2023).

2.4.2 Building Performance Theory

This theory provides a framework for assessing how architectural elements influence functional outcomes such as thermal comfort, daylighting, ventilation, acoustics, and energy consumption (Graham, 2003). Applied to DSF systems, this theory facilitates the evaluation of glazing configurations, cavity depths, and shading devices in regulating cooling loads within Abuja's hot-humid climate. It further resonates with SDG 3 (Good Health and Well-being) by emphasizing occupant comfort and productivity, and SDG 9 (Industry, Innovation, and Infrastructure) through the adoption of innovative façade technologies that enhance building efficiency.

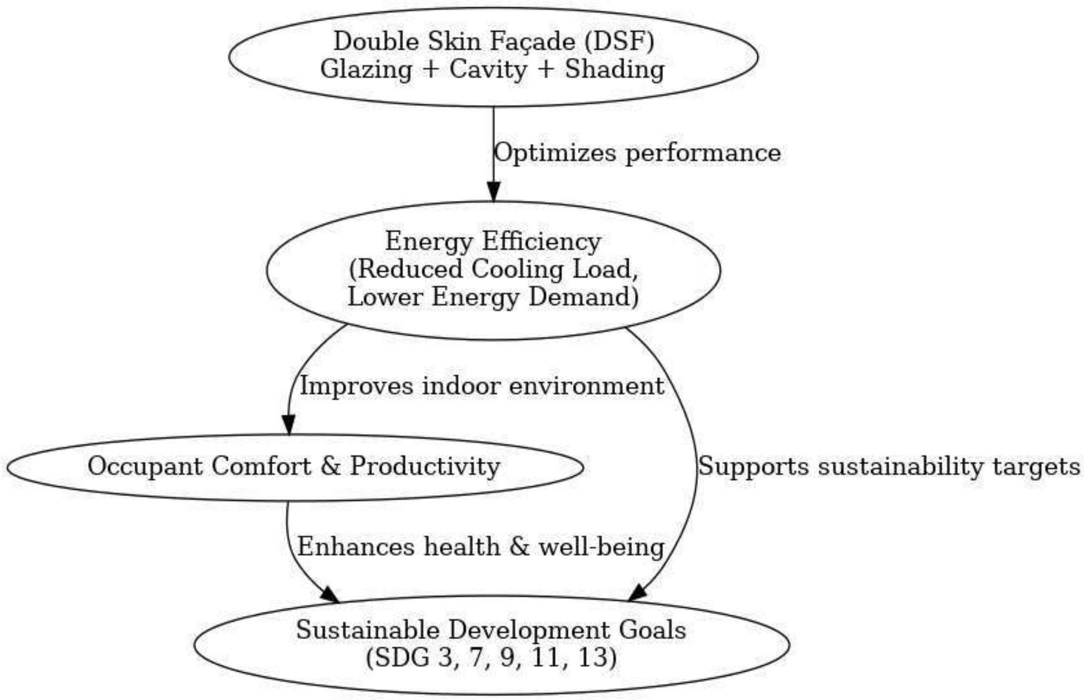

Figure 1: Conceptual Framework linking Double Skin Façade, Energy Efficiency, and SDGs Source: Author's construct (2025), adapted from Zin et al. (2020), Schmid et al. (2019), and UN (2023).

Collectively, these frameworks establish DSFs as both a sustainable design approach and a performance-oriented building system (Figure 1). They serve as the theoretical foundation for evaluating glazing strategies in this study, ensuring that the outcomes advance scholarly discourse while supporting global sustainability goals (Zin et al. 2020; Schmid et al. 2019; UN, 2023).

3.0 METHODOLOGY

This section describes the methodology used in this study. It describes the study location, the study area and methods chosen for this study.

3.1 The Study Area: Abuja

Abuja is the study area located in the central part of Nigeria north of the confluence of the Niger and Benue Rivers. This city lies between the latitude of 8°25`N to 9°25`N and longitude 6°45`E to 7°45`E and has a land area of 8000 km^2 which makes it almost two and a half times the size of Lagos State. It is bounded by Kaduna State to the North, Kogi State to the south, and Niger State to the West and Nasarawa State to the East (Isma'il, & Abubakar, 2024). Abuja has a population of about 8 million as projected from 2006 National Population Commission Census (NPC, 2019) (Figure 2).

Abuja is witnessing rapid growth in shopping centers and malls, creating a rising demand for energy-efficient commercial building designs that can adapt to the environment. The city's composite climate characterized by hot-dry and hot-humid seasons with mean temperatures often exceeding 35°C and intense solar radiation intensifies cooling energy needs. These climatic extremes highlight the urgent need to rethink façade design strategies for reducing energy consumption.

Figure 2: Map of Abuja in National context

Source: Department of Geography and Planning, University of Jos, 2024.

3.2 Case Study: Jahi District Modern Shopping Mall

Jahi is a locality in Municipal Area Council, Federal Capital Territory. Jahi is situated nearby to the village Jiru, as well as near the locality Kadobunkuro. The Jahi District Modern Shopping Mall was selected as the case study due to its extensive glazed façades, orientation, and material use, which provide a realistic basis for double skin façade simulation and analysis. Its accessibility for data collection and location in a rapidly developing commercial district further underscore its relevance to the research context.

3.3 Research Design

A simulation-based quantitative research design was employed to assess the impact of DSF glazing configurations on building cooling demand. This approach enabled objective comparison of thermal and energy performance across glazing options.

3.4 Simulation Setup

A baseline model representing a conventional shopping mall without DSF was developed. DSF alternatives were then simulated using a 1-meter cavity width, which literature identifies as an optimal balance between ventilation and insulation (Al Tekreeti, 2015; Saroglou et al. 2020). Abuja climatic data was integrated into the model, focusing on cooling loads since heating is negligible (Figure 3)

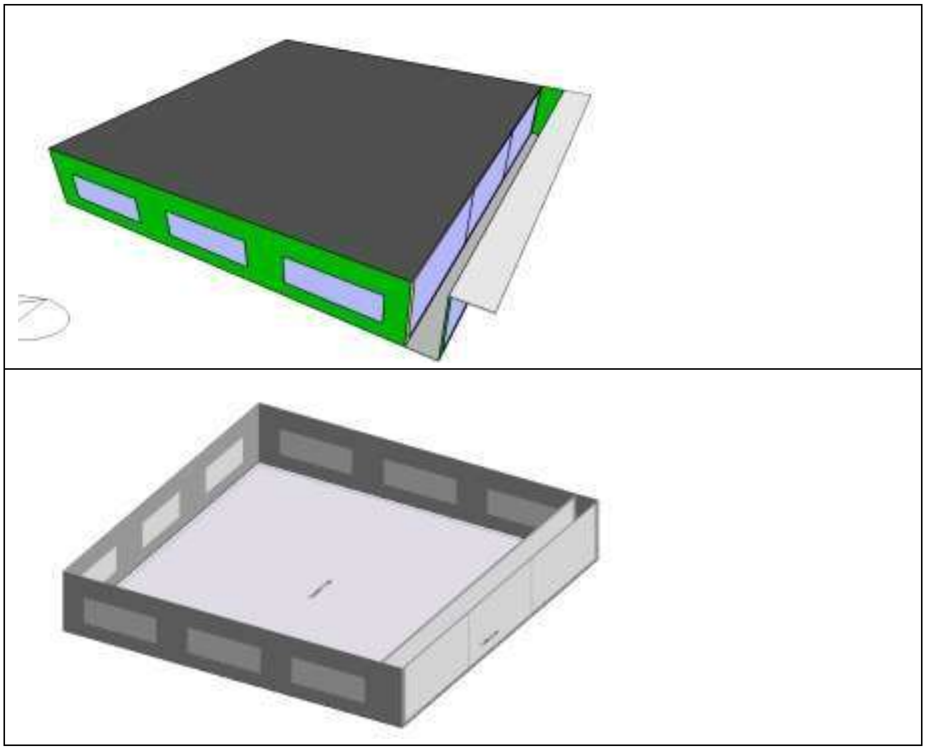

Figure 3: Glazing on double skin façade Source: Authors simulation, 2025.

3.5 Design Variables

The independent variables were glazing type (thermochromic, low-E, tinted, clear) and pane categories (single, double, triple) (Table 1). The dependent variable was cooling energy demand.

Table 1: Independent Variables

	Category of Glass	Type of Glass
Base Case (no DSF)	–	
Thermochromic	Single, Double, Triple	
Low-emissivity (low-E)	Single, Double, Triple	
Tinted	Single, Double, Triple	
Clear glass	Single, Double, Triple	

Source: Field work, 2025.

4.0 RESULTS AND DISCUSSION

4.1 Monthly Energy Demand of Glazing Configurations

Table 2: Monthly Cooling Energy Demand of Glazing Configurations in Abuja (kWh)

Glazing Type	April (Peak)	August (Lowest)	Remarks

Base Case (No DSF)	9,961.36	7,762.00	Highest demand across months
Thermochromic	8,097.00	6,818.00	Most efficient; dynamic tinting reduces heat gain
Low-E Single Pane	10,165.00	8,334.00	Poor insulation, least efficient
Low-E Double Pane	8,224.00	6,933.00	Very effective; optimal balance of insulation & daylight
Low-E Triple Pane	9,558.00	7,871.00	Better than single-pane but less efficient than double
Tinted Single Pane	8,226.00	6,931.00	Moderate efficiency; glare control benefit
Tinted Double Pane	9,528.00	7,808.00	Less effective than low-E options
Tinted Triple Pane	8,265.00	6,972.00	Improved control, slight daylight reduction
Clear Single Pane	9,742.00	7,982.00	High heat gain, poor performance
Clear Double Pane	8,380.00	7,066.00	Improved thermal efficiency
Clear Triple Pane	9,714.00	7,982.00	Inefficient despite thickness

4.2 Annual Energy Demand of Glazing Configurations

Table 3: Annual Cooling Energy Demand of Glazing Configurations in Abuja (MWh)

Glazing Type	Annual Energy Demand (MWh)	Rank
Base Case (No DSF)	104,288.10	Worst
Thermochromic	90,585.77	Best
Low-E Single Pane	112,265.00	Worst performer
Low-E Double Pane	92,165.00	2nd Best
Low-E Triple Pane	105,758.00	Low efficiency
Tinted Single Pane	91,980.00	3rd Best
Tinted Double Pane	96,049.00	Moderate
Tinted Triple Pane	92,521.00	Comparable to Low-E Double
Clear Single Pane	107,775.00	Poor performance
Clear Double Pane	94,010.00	Mid efficiency
Clear Triple Pane	107,446.00	Inefficient

Glazing Type	April (Peak)	August (Lowest)	Remarks
Base Case (No DSF)	9,961.36	7,762.00	Highest demand
Thermochromic	8,097.00	6,818.00	Most efficient
Low-E Double Pane	8,224.00	6,933.00	Optimal insulation & daylight
Tinted Single Pane	8,226.00	6,931.00	Moderate efficiency
Clear Double Pane	8,380.00	7,066.00	Better than base case
Others (Single clear, low-E single, tinted double, triple panes)	9,528–10,165	7,808–8,334	Poor performance

Annual Cooling Demand

Table 5: Annual consumption trends confirm monthly results.

Glazing Type	Annual Demand (MWh)	Rank
Base Case (No DSF)	104,288.10	Worst
Thermochromic	90,585.77	Best
Low-E Double Pane	92,165.00	2nd Best
Tinted Single Pane	91,980.00	3rd Best
Clear Double Pane	94,010.00	Moderate
Others (Single clear, low-E single, triple variants)	105,000–112,000	Inefficient

Source: Field work, 2025

4.3 Monthly Cooling Demand

Table 4 presents monthly variations in energy demand. The base case recorded the highest peak demand (9,961 kWh in April), while thermochromic glazing and low-E double panes achieved the lowest (8,097 kWh and 8,224 kWh respectively).

4.3 Discussion

The results demonstrate that façade optimization significantly influences cooling energy demand in shopping malls within Abuja's composite climate. While conventional façades (base case) incur excessive energy demand, integrating DSF with advanced glazing reduces cooling loads by up to 14% annually. Thermochromic glazing dynamically regulates solar gain, while low-E double panes balance insulation with daylight transmission. Triple-pane systems, though more insulated, sometimes increased energy demand due to reduced daylight and higher reliance on artificial lighting. These results align with Al Tekreeti (2015) and Saroglou et al. (2020), affirming that optimal DSF glazing can achieve measurable energy savings in hot-humid climates (Table 1 - 5).

5.0 CONCLUSION

This study assessed the effectiveness of DSF glazing systems in improving energy efficiency in shopping mall buildings within Abuja's hot-humid climate. Results showed that thermochromic and low-E double-pane glazing achieved the greatest reductions in both monthly and annual cooling demands, lowering energy consumption by over 13% compared to conventional façades. Conversely, single-pane and untreated clear glass performed poorly due to excessive heat gain. These findings confirm that DSF systems, when optimized with climateresponsive glazing, can significantly enhance sustainability and reduce operational energy costs in commercial buildings.

6.0 RECOMMENDATIONS

The conclusions from this study create a basis for the improvement of our environment to make it more sustainable in line with the Vision 2030.This necessitates the following recommendations:

1. There is the need to adopt thermochromic and low-E double-pane glazing in commercial developments to achieve optimal energy savings and comfort.
2. DSF systems should be integrated into building codes and guidelines for commercial buildings in Nigeria to promote energy-efficient design.
3. There is the need to avoid single-pane glazing in new commercial developments due to poor thermal performance.
4. Future research should incorporate daylighting quality and cost-benefit analyses to complement energy performance results.

7.0 CONTRIBUTION TO KNOWLEDGE

This study provides empirical evidence on the performance of DSF glazing in Abuja's hot-humid climate, identifying thermochromic and low-E double-pane glazing as the most effective, with over 13% energy savings. The findings demonstrate how localized, climateresponsive façade strategies can significantly enhance energy efficiency and sustainability in resource-constrained contexts.

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Material Science and Engineering International Research Journal
ISSN: 2997-6685|
Volume 12 Issue 3, July-September, 2024
Journal Homepage: https://ethanpublication.com/articles/index.php/E30
Official Journal of Ethan Publication

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