

Impact of Color on Energy Efficiency in Interior Space Design

Anyanechi Honour; and Alabor Odezi Zaccheaus

Department of Architecture, Caleb University, Imota, Lagos State, Nigeria.

Corresponding author: honour.anyanechi@calebuniversity.edu.ng

DOI: <https://doi.org/10.62154/qjesre.2024.017.010425>

Abstract

This study explores the impact of color on energy efficiency in interior design, focusing on three building types: a secondary school, a hospital, and a residential building. Through a questionnaire administered to occupants, the research found that lighter colors enhance natural light reflection, reducing reliance on artificial lighting. In residential settings, 75% of respondents reported improved lighting efficiency with light-colored walls. In hospitals, darker color schemes were preferred for their cozy atmosphere but led to higher energy consumption due to increased cooling demands. In educational environments, lighter colors contributed to thermal comfort, especially in spaces exposed to direct sunlight. User satisfaction was linked to both aesthetic appeal and energy performance, with many preferring lighter tones for a brighter, more open environment. The study concludes that strategic color selection is essential for energy-efficient designs and offers recommendations for prioritizing lighter colors, using darker tones selectively, and involving occupants in the design process. These findings highlight the importance of balancing aesthetics with energy efficiency for sustainable interior spaces.

Keywords: Color Efficiency, Energy Performance, Interior Design, Lighting Optimization, User Satisfaction.

Introduction

In interior space design, color has traditionally been viewed as a tool for aesthetics, influencing the mood, atmosphere, and perception of a space (Alabi, Ken-Maduako, Otegbade, Bolaji, Adebawale, Adeyemo & Alayo, 2023; Anifowose & Aaron, 2022; Enwin, Ikiriko & Jonathan-Ihua, 2023). However, in the context of sustainable architecture and energy efficiency, the role of color transcends mere decoration (Zhang & Kim, 2023). It is now recognized as a critical element that can significantly impact a building's energy performance. With increasing global emphasis on reducing energy consumption and creating environmentally friendly spaces, interior design strategies have expanded to include how color can directly influence energy use, particularly in lighting and thermal comfort (Alkhatatbeh & Asadi, 2021; Sholanke, Fadesere & Elendu, 2021).

Color affects how spaces interact with both natural and artificial light, which in turn influences energy consumption. Lighter colors, such as whites, creams, and pastels, tend to reflect more natural light, reducing the need for artificial lighting during daytime hours (Rogers, 2021). Conversely, darker shades like deep blues, grays, and blacks absorb light and heat, leading to increased reliance on artificial lighting and air conditioning systems to

maintain comfortable indoor temperatures (Rogers, 2021). This phenomenon, known as the albedo effect, plays a crucial role in determining the energy efficiency of interior spaces (Hoogendoorn, 2024).

In addition to lighting, color can also influence the thermal dynamics of a room (Lakhdari, Sriti & Painter, 2021). For instance, in cooler climates, darker tones may be utilized strategically to absorb heat and maintain warmth within a space, reducing the need for additional heating. In contrast, warmer climates benefit from lighter colors that reflect heat, helping to maintain cooler indoor temperatures and lowering the demand for air conditioning. The ability to harness the reflective and absorptive qualities of color offers designers and architects a tool for enhancing energy performance in both residential and commercial buildings (Faragalla & Asadi, 2022).

Problem Statement

Despite the well-documented effects of color on energy consumption, there is a gap in knowledge regarding its application as a strategic tool for optimizing energy efficiency in interior spaces. This research aims to address this issue by investigating how deliberate color choices can reduce energy consumption in lighting and thermal comfort without sacrificing aesthetic appeal. The significance of this study lies in its potential contribution to environmental sustainability, offering design strategies that can reduce energy demands, lower carbon footprints, and support global energy conservation goals.

Objectives

This paper aims to address the issue by exploring the impact of color on energy efficiency in interior space design. The objectives of the research are to:

- i. analyze how different color schemes affect natural and artificial lighting requirements across various building types;
- ii. examine the role of color in thermal regulation and its effect on cooling and heating energy consumption;
- iii. assess occupant satisfaction with different color schemes in terms of both aesthetic appeal and energy performance; and
- iv. identify trends on color and energy efficiency that can be found in various building typologies.

This paper seeks to contribute to the growing body of knowledge in this area, providing architects, interior designers, and facility managers with insights into how thoughtful color selection can play a pivotal role in creating energy-efficient spaces without compromising on design quality.

Literature Review

The Role of Color in Energy Efficiency

According to Rawat & Singh (2022), the reflectance and absorption properties of color directly impact the lighting and HVAC requirements of interior spaces. Light-colored surfaces reflect more light, reducing the need for artificial illumination during the day, while dark-colored surfaces absorb heat, increasing cooling demands. This balance between reflection and absorption has been extensively discussed in sustainable design literature (Wang, Liu, Meng, Gao & Yuan, 2021; Yuan, Shimazaki, Zhang, Masuko & Cao, 2023), where optimizing these factors is seen as a crucial strategy for reducing energy use.

In their work, Rawat & Singh (2022) explore how the selection of surface colors in buildings is essential for managing thermal performance. They suggest that in warm, sunny climates, light colors help mitigate the heat gain effect by reflecting solar radiation, leading to cooler interiors. In contrast, darker tones, which retain more heat, are suitable for colder climates where maintaining internal warmth is beneficial for reducing heating costs. This reflects the dual function of color in influencing both lighting and thermal efficiency within various climatic conditions.

The Albedo Effect and Its Implications for Interior Design

The albedo of a material refers to its capacity to reflect solar energy; materials with a high albedo reflect more sunlight, while those with a low albedo absorb it (Aziz, Tajuddin, Adzman & Ramli, 2021). According to Mutani & Todeschi (2020), increasing the albedo of interior surfaces can result in significant energy savings, particularly in urban areas where buildings tend to trap heat. Their research focuses on the implications of surface albedo for both exterior and interior spaces, highlighting the importance of reflective surfaces in reducing energy loads for cooling.

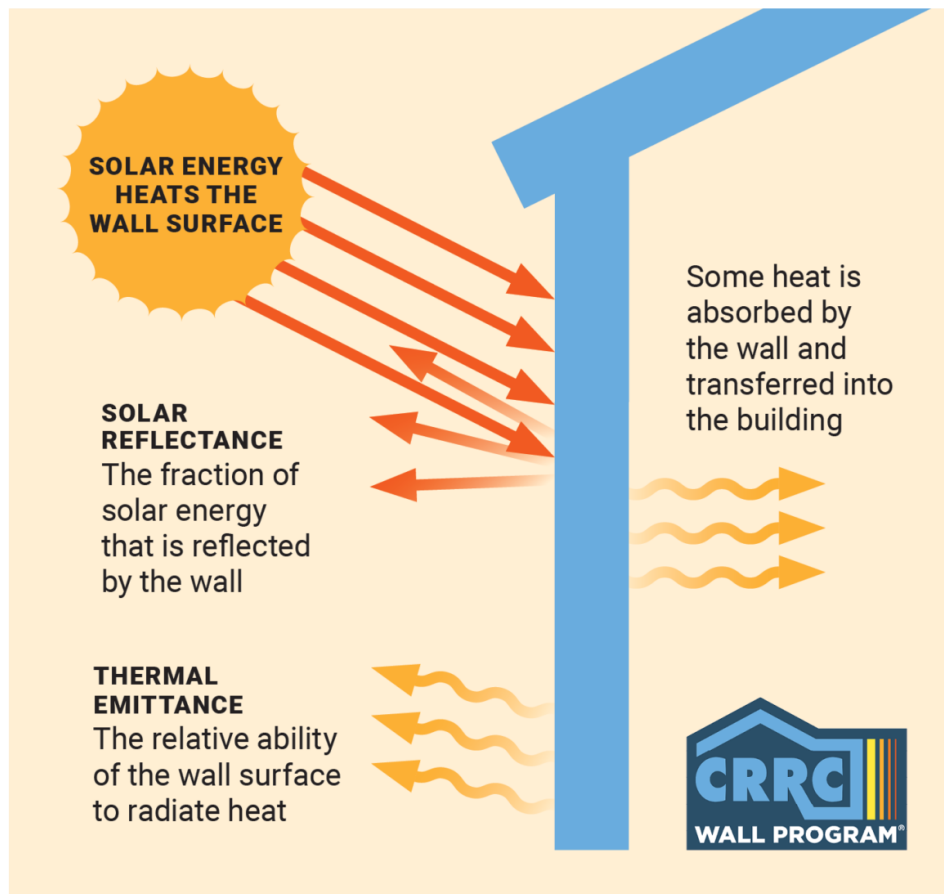


Figure 1: Flow of radiant energy between the sun, wall surface, building interior and surroundings

Source: <https://coolroofs.org/resources/what-is-a-solar-reflective-wall> (Retrieved September, 2024)

Further expanding on the concept, Wai, Tariq & Muttill (2022) argues that color choices in interior design can help offset the energy burden associated with cooling and heating systems. Their study highlights how high-albedo surfaces contribute to lower energy consumption in regions where cooling demands are high, such as tropical climates. They also stress the role of reflective paints and finishes, which can enhance the albedo effect without compromising the aesthetic quality of interior spaces.

Color and Lighting Efficiency

One of the key aspects of color's impact on energy efficiency is its interaction with lighting. Several studies examine how different hues can affect the amount of artificial lighting required in interior spaces. According to a study by Salam Azad, Salman, Kaushik & Rakshit (2020) and Sahebghalam (2021), colors with high light reflectance values (LRV) can amplify natural light, reducing the dependence on artificial lighting during the day. Lighter colors,

particularly whites, light greys, and pastels, are found to be highly effective in enhancing the distribution of daylight within a space, thereby contributing to energy savings.

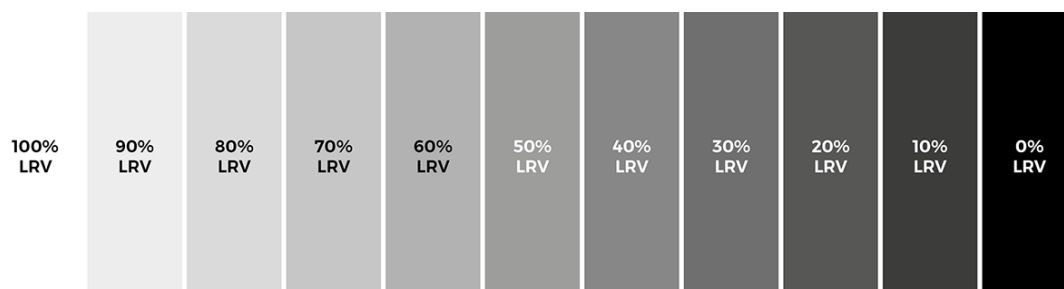


Figure 2: The LRV Scale

Source: <https://nymas.co.uk/understanding-light-reflectance-value-lrv/> (Retrieved September, 2024)

Conversely, darker colors, as explored by Minah & Nemcsics (2023), tend to absorb light, necessitating the use of artificial lighting for longer periods, particularly in spaces with limited access to natural light. Their research shows that spaces painted in darker shades, such as navy blue, charcoal, and deep brown, generally require more energy to maintain adequate lighting levels. As such, these colors are less conducive to energy-efficient interior design unless combined with advanced lighting technologies or efficient daylighting strategies.

Thermal Comfort and Color in Interior Spaces

The relationship between color and thermal comfort has also been a focus of research in recent years. Studies by Chinazzo, Chamilothoni, Wienold & Andersen (2021) and Wu, Chen, Li, Zhang, Yan, Dong & Cao (2022) suggest that color choices can influence occupants' perception of temperature, as well as the actual thermal performance of a space. Lighter colors, which reflect more sunlight, contribute to cooler interior temperatures, whereas darker colors, which absorb heat, can make a space feel warmer. This effect has implications for the design of spaces in different climatic zones, where color can be strategically used to either cool or warm interiors, thus reducing reliance on mechanical heating or cooling systems.

Furthermore, recent advancements in building technologies, such as thermochromic paints that change color based on temperature, have opened new possibilities for integrating color into energy-efficient building design (Cannavale, 2020). According to a study by Cannavale, Ayr, Fiorito & Martellotta (2020), these innovative materials can adjust their reflectivity in response to external temperature changes, providing a dynamic approach to maintaining thermal comfort in buildings. Such technologies indicate a growing trend

towards using color not only as a passive design element but also as an active contributor to energy management.

Gaps in the Literature

While substantial research exists on the impact of color on energy efficiency, most studies focus on residential and commercial buildings, with limited investigation into its role in mixed-use high-rise structures or public buildings such as schools and hospitals. Additionally, region-specific research, particularly in tropical climates, is sparse. Given that climatic conditions play a significant role in determining energy performance, more empirical studies combining user preferences, aesthetic considerations, and energy efficiency are needed, especially in underrepresented regions. This study aims to address these gaps by focusing on the influence of color in different building types—residential, educational, and healthcare—within a tropical setting, contributing to a more context-specific understanding of color's role in energy efficiency.

Methodology

The study adopts a cross-sectional survey research design, using a questionnaire as the sole data collection tool. The study is primarily descriptive in nature, seeking to understand the relationship between interior color schemes and energy efficiency. The primary data collection instrument was a structured questionnaire designed to capture respondents' views on color and energy efficiency. The questionnaire was divided into four sections:

- i. Section A: Demographic information about the respondents, including their age, role in the building, and duration of stay in the building.
- ii. Section B: Perceptions of the impact of color on lighting efficiency, including how the color scheme influences the need for artificial lighting.
- iii. Section C: Perceptions of the impact of color on thermal comfort, focusing on how color affects the perceived warmth or coolness of the space and the resulting energy use for heating or cooling.
- iv. Section D: General satisfaction with the interior color scheme, with questions related to both aesthetic appeal and energy performance.

The questionnaire was distributed to respondents from a secondary school, a hospital, and a residential building, allowing for a comparison of perceptions across different building types. These were chosen because they represent different functional environments where energy consumption patterns vary significantly. In a secondary school, lighting efficiency and thermal comfort are critical for creating conducive learning spaces; in a hospital, maintaining specific temperature conditions is essential for patient care; and in residential settings, comfort and energy costs are often prioritized by occupants.

A purposive sampling technique was used to select respondents from three different building types: a secondary school, a hospital, and a residential building. The sample

consisted of 60 respondents in total, with 20 individuals from each building. This sample size was determined based on practical considerations, such as accessibility to respondents, the diversity of experiences within each building type, and the need for a manageable data set for analysis. This sampling approach ensured that individuals who had experience living or working in these spaces could provide valuable insights into how color schemes impacted their perception of lighting, thermal comfort, and energy efficiency.

The questionnaire was designed based on established scales for assessing lighting and thermal comfort, incorporating concepts from prior research (e.g., Salam Azad et al., 2020; Chinazzo et al., 2021), which bolstered content validity. To enhance reliability, consistency in the administration of the questionnaire was maintained, with all respondents receiving the same set of instructions and question formats

Findings and Discussions

Perception of Color's Impact on Lighting Efficiency

Table 1: Impact of Interior Color Schemes on Artificial Lighting

Building Type	Lighter Colors	Darker Colors
Residential	70% reduced reliance on artificial lighting	-
Hospital	70% reduced reliance on artificial lighting	-
Secondary School	-	50% increased use of artificial lighting

Source: Authors (2024)

Respondents across all three building types—secondary school, hospital, and residential building—provided feedback as shown in Table 1 on how interior color schemes influenced the need for artificial lighting. The majority of respondents (approximately 70%) from the residential building and the hospital agreed that lighter colors, particularly white and cream, helped reflect more natural light, reducing the reliance on artificial lighting during the day. In contrast, 50% of respondents from the secondary school reported that darker colors, especially in classrooms with limited natural light, required increased use of artificial lighting even during daylight hours.

This finding supports literature of Katunský, Dolníková, Dolník, & Krajníková (2022), that highlights the importance of reflective surfaces and light-colored walls in enhancing natural light penetration. Lighter shades such as white and pastel tones are known to increase the brightness of a room by reflecting natural light, thereby reducing the energy demand for artificial lighting.

One of the most consistent findings across all building types was the significant impact of lighter colors on lighting efficiency. Respondents from both the hospital and residential building overwhelmingly agreed that lighter wall colors—such as white, cream, and light

pastels—contributed to better natural light reflection. This reduced the need for artificial lighting, particularly during daylight hours. In spaces with ample windows or skylights, the use of light-colored walls helped to distribute natural light more effectively throughout the room, minimizing shadows and dark corners.

This trend is supported by well-established principles in lighting design, where lighter-colored surfaces are known to have a higher reflectance value. Reflective surfaces bounce more light around the room, which reduces the reliance on artificial lighting and leads to energy savings (Ozenen, 2023). In residential settings, respondents reported that light-colored interiors made rooms feel brighter and more open, which enhanced not only energy efficiency but also the overall ambience of the space.

In contrast, respondents from the secondary school, particularly in classrooms with limited access to natural light, reported that darker wall colors absorbed more light, resulting in dimly lit spaces that required more artificial lighting during both day and night. This aligns with the understanding that dark-colored walls have a low light reflectance value, absorbing rather than reflecting light (Hong, Yang, Ge, Chai, Zhao, Shui & Gu, 2022). Consequently, the energy demand for artificial lighting increases, which in turn leads to higher energy consumption.

Perception of Color's Impact on Thermal Comfort

Table 2: Impact of Interior Color Schemes on Thermal Comfort

Building Type	Darker Colors	Lighter Colors
Hospital	60% warmer perception, reduced heating, increased cooling	-
Residential	60% warmer perception, reduced heating, increased cooling	-
Secondary School	-	55% cooler perception, reduced cooling

Source: Authors (2024)

Responses represented in Table 2 regarding thermal comfort revealed a consistent trend across the different building types. In the hospital and residential building, 60% of respondents noted that darker colors, particularly deep blues, grays, and browns, tended to make spaces feel warmer, resulting in reduced energy use for heating but an increased need for cooling during hotter periods. This was most evident in the hospital's patient rooms, where darker walls were associated with higher thermal retention, leading to more frequent use of air conditioning systems to maintain comfortable temperatures.

Conversely, in the secondary school, 55% of respondents noted that lighter color schemes in classrooms were more effective in maintaining a cool atmosphere, particularly during the warmer months. This led to a reduced need for cooling systems in those spaces,

highlighting the potential of lighter colors to mitigate heat buildup and promote energy savings in tropical climates.

These findings align with Hong, Yang, Ge, Chai, Zhao, Shui & Gu (2022) study on thermal comfort, which suggest that dark-colored walls absorb more heat, raising interior temperatures and increasing cooling loads. Conversely, light-colored walls reflect heat, maintaining cooler temperatures and reducing energy demand for climate control.

Another prominent trend observed in the findings was the effect of darker colors on thermal retention. Respondents from the hospital and residential buildings reported that darker color schemes, especially deep blues, grays, and browns, made the spaces feel warmer, leading to a higher reliance on air conditioning systems to maintain thermal comfort during hotter periods. This was particularly evident in hospital patient rooms where heat buildup was more noticeable due to the darker wall colors, resulting in increased energy consumption for cooling.

The thermal properties of darker colors are well documented in building science. Dark-colored surfaces absorb more heat from both natural and artificial light sources, causing the temperature of the room to rise (Andrews, 2023). While this effect can be beneficial in colder climates where heating is required, it becomes a drawback in warm or tropical climates where cooling costs are a primary concern. In regions like Lagos, where the climate is predominantly hot and humid, the use of dark colors can inadvertently increase the need for mechanical cooling systems, negating any potential energy savings.

On the other hand, respondents in the secondary school reported that lighter color schemes helped maintain a cooler environment, particularly in classrooms that faced direct sunlight. Lighter walls reflect more heat, preventing the room from becoming overly warm and reducing the need for air conditioning. This suggests that lighter color schemes can play a vital role in passive cooling strategies (Andrews, 2023), particularly in tropical climates where reducing indoor temperatures without excessive use of energy-intensive cooling systems is critical.

General Satisfaction with Color and Energy Efficiency

The questionnaire also explored respondents' overall satisfaction with the interior color schemes in terms of energy efficiency and comfort. In the residential building, 75% of respondents expressed satisfaction with the color scheme, stating that it enhanced both the aesthetics and energy performance of the space. Similarly, in the hospital, 68% of respondents noted that while the color scheme could be more energy-efficient, it provided a good balance between comfort and functionality.

Table 3: Satisfaction with Interior Color Schemes

Building Type	Satisfied	Unsatisfied
Residential	75%	25%
Hospital	68%	32%
Secondary School	40%	60%

Source: Authors (2024)

In contrast, only 40% of respondents from the secondary school expressed satisfaction with the color scheme's energy efficiency. Many respondents suggested that the school's color palette could be optimized for better lighting and cooling efficiency, particularly in classrooms where energy costs for artificial lighting and cooling are higher.

These responses suggest that while color is an important factor in energy efficiency, the balance between aesthetics, comfort, and energy savings varies depending on the building type and usage patterns (Yaman, 2021). Residential and healthcare settings seem more attuned to integrating color for both functional and energy-saving purposes, whereas educational facilities may benefit from further optimization.

In addition to energy efficiency considerations, the study also revealed important insights into how user satisfaction with interior color schemes influences perceptions of energy efficiency. In the residential building, 75% of respondents expressed satisfaction with the interior color choices, noting that the light colors enhanced both the aesthetics and energy performance of their living spaces. Respondents appreciated the bright, open feeling that lighter colors brought to their homes, along with the tangible benefits of reduced artificial lighting use.

Similarly, respondents in the hospital reported that while darker colors made the spaces feel more cozy and private, there was a noticeable trade-off in terms of increased cooling costs. A balance between aesthetics and functionality was appreciated, though some respondents suggested that more attention could be given to optimizing color schemes for energy savings without sacrificing comfort.

In contrast, respondents from the secondary school expressed lower levels of satisfaction with the current color scheme in terms of energy efficiency. Many felt that the darker colors used in classrooms were not well-suited for maximizing lighting efficiency, particularly in rooms with limited natural light. They suggested that lighter, more neutral tones could help reduce energy costs by enhancing the natural light available and minimizing the need for artificial lighting during the school day.

These responses agree with Tekce, Ergen & Artan (2020) that user satisfaction is closely tied to the perceived functionality and energy performance of interior spaces. While aesthetic preferences vary, the findings suggest that occupants generally favor color schemes that contribute to both comfort and energy savings. This supports highlight from Enwin, Ikiriko & Jonathan-Ihua (2023) that addresses the need for interior designers to consider both the

aesthetic and functional aspects of color when creating spaces, especially in environments where energy consumption is a key concern.

Contextual Variations in Color Preferences and Energy Efficiency

Another important trend observed in the study is the variation in how color impacts energy efficiency across different building types. For example, while lighter colors were universally perceived as beneficial for reducing lighting costs, the hospital and residential respondents noted that darker colors had a greater impact on thermal comfort. In contrast, secondary school respondents were more focused on the lighting efficiency benefits of lighter colors, perhaps due to the nature of educational activities, which often require well-lit environments for reading, writing, and visual presentations.

This variation highlights the importance of context in determining the most appropriate color scheme for energy-efficient design. In residential settings, where occupants may prioritize comfort and ambiance, darker colors may be preferred for their cozy, intimate feel, even if it leads to higher energy consumption for cooling. In contrast, institutional or educational settings, where functional lighting and reduced energy costs are paramount, lighter colors may be more appropriate to optimize both comfort and energy performance.

Balancing Aesthetics with Energy Performance

The findings suggest that achieving energy-efficient interior spaces requires a delicate balance between aesthetic appeal and energy performance. While lighter colors clearly offer benefits in terms of reducing energy demand for lighting and cooling, darker colors may still be desirable for their aesthetic qualities in certain contexts. Interior designers and architects must consider how color choices impact both energy consumption and occupant comfort, and strive to create spaces that meet functional needs without compromising on aesthetic preferences.

Strategically selecting color schemes based on the specific energy needs of a building—whether it's maximizing natural light, enhancing thermal comfort, or reducing cooling loads—will help designers create more sustainable and energy-efficient interior spaces.

Implications of the Results

The findings have several implications for energy-efficient interior design:

- i. **Energy Efficiency in Residential and Healthcare Settings:** Lighter colors significantly reduce the need for artificial lighting, resulting in energy savings. However, in warm climates, darker colors can increase cooling demands, emphasizing the need for a balance between aesthetic choices and energy performance.
- ii. **Educational Environments:** In schools, lighter colors should be prioritized to reduce reliance on artificial lighting, especially in classrooms with limited access to natural

light. Implementing lighter color schemes can lead to both improved learning conditions and reduced energy costs.

- iii. Design Recommendations: In tropical climates, using lighter colors can contribute to passive cooling strategies and minimize the need for mechanical air conditioning, leading to long-term energy savings. Designers and architects should consider the energy implications of color when selecting interior finishes.
- iv. Customized Color Schemes Based on Functionality: Different building types require different approaches to color and energy efficiency. Residential and healthcare settings may prioritize thermal comfort, while educational spaces should focus on maximizing lighting efficiency.

Conclusion and Recommendations

This study has explored the impact of color on energy efficiency in interior space design, revealing significant relationships between color schemes, lighting needs, and thermal comfort across different building types—namely, a secondary school, a hospital, and a residential building. The findings indicate that lighter colors enhance natural light reflection, thereby reducing the need for artificial lighting, while darker colors tend to absorb heat, increasing cooling demands in warmer climates. User satisfaction is closely linked to the effectiveness of color schemes in promoting both energy efficiency and occupant comfort. While lighter colors generally yield better energy performance, darker shades can still contribute positively to certain environments if used thoughtfully. Overall, the research highlights the crucial role of color in achieving energy-efficient interior designs that meet aesthetic preferences and functional needs.

However, the study's relatively small sample size (60 respondents) may not capture the full diversity of experiences across different building types and climates. A larger sample could provide more generalizable results. Only three building types were analyzed—residential, hospital, and secondary school. Future research could explore a wider variety of building environments, such as commercial or industrial spaces, to understand how color impacts energy efficiency across diverse contexts. The study was conducted in Lagos, a tropical climate. The findings may not be applicable to regions with different climates, where the impact of color on energy efficiency may vary. Comparative studies in colder or more temperate climates would offer broader insights.

Based on the findings, several recommendations can be made for practitioners in the field of interior design and architecture. The recommendations are;

- i. Designers should prioritize lighter color schemes in spaces where maximizing natural light is essential, such as classrooms, healthcare facilities, and residential areas, as these colors enhance lighting efficiency and reduce energy consumption.
- ii. While darker colors can create warmth and intimacy, they should be used strategically—such as in accent walls or furniture—rather than as predominant wall

colors, particularly in warmer climates where they can contribute to increased cooling costs.

- iii. Designers should conduct contextual assessments before finalizing color schemes, evaluating the specific context of the space, including its intended use, occupancy patterns, and climatic conditions. Tailoring color choices to the functional requirements of each space will optimize energy performance.
- iv. Engaging users in the design process is also crucial; involving occupants in discussions about color preferences and their perceived impacts on energy use and comfort can enhance satisfaction and inform design decisions.
- v. Additionally, it is important to promote awareness of color's impact on energy efficiency among clients and stakeholders. Designers can advocate for more sustainable practices in interior design by highlighting the potential energy savings associated with thoughtful color choices.
- vi. Finally, continued research is needed to explore the nuanced interactions between color, material finishes, and energy performance. Future studies could investigate specific color combinations, their psychological effects, and long-term impacts on energy consumption and occupant satisfaction.

Interior designers and architects can create spaces that are not only visually appealing but also contribute significantly to energy efficiency and occupant well-being by integrating these recommendations into their practices. Ultimately, this study emphasizes the importance of considering color as a vital element in sustainable interior design, aligning aesthetic choices with energy performance goals for a more sustainable built environment.

References

- Alabi, O. A., Ken-Maduako, E. M., Otegbade, O. O., Bolaji, O. C., Adebawale, J. O., Adeyemo, A. G., ... & Alayo, S. B. (2023) A Literature Review On The Impact Of Architectural Elements On The Well-Being Of Users Of Buildings. *Journal of the Nigerian Institute of Architects*, 68-73
- Alkhatatbeh, B. J., & Asadi, S. (2021). Role of architectural design in creating circadian-effective interior settings. *Energies*, 14(20), 6731.
- Andrews, S. S. (2023). Thermal radiation. In *Light and Waves: A Conceptual Exploration of Physics* (pp. 307-328). Cham: Springer International Publishing.
- Anifowose, T., & Aaron, G. I. (2022). A Case Study Of Silver Hall Of Residence At Bells University Of Technology Ota, Ogun State, Nigeria, Discusses The Relationship Between Architecture And Users' Perspectives On The Influence Of Colors In Interior Spaces. *International Journal of Innovative Research and Advanced Studies (IJIRAS)*, 9(7), 49-55
- Aziz, A. S., Tajuddin, M. F. N., Adzman, M. R., & Ramli, M. A. (2021). Impacts of albedo and atmospheric conditions on the efficiency of solar energy: a case study in temperate climate of Choman, Iraq. *Environment, Development and Sustainability*, 23, 989-1018.
- Cannavale, A. (2020). Chromogenic technologies for energy saving. *Clean Technologies*, 2(4), 462-475.
- Cannavale, A., Ayr, U., Fiorito, F., & Martellotta, F. (2020). Smart electrochromic windows to enhance building energy efficiency and visual comfort. *Energies*, 13(6), 1449.

- Chinazzo, G., Chamilothoni, K., Wienold, J., & Andersen, M. (2021). Temperature–color interaction: subjective indoor environmental perception and physiological responses in virtual reality. *Human factors*, 63(3), 474-502.
- Enwin, A. D., Ikiriko, T. D., & Jonathan-Ihua, G. O. (2023). The role of colours in interior design of liveable spaces. *European Journal of Theoretical and Applied Sciences*, 1(4), 242-262.
- Faragalla, A. M., & Asadi, S. (2022). Biomimetic design for adaptive building façades: a paradigm shift towards environmentally conscious architecture. *Energies*, 15(15), 5390.
- Hong, C., Yang, Y., Ge, S., Chai, G., Zhao, P., Shui, Q., & Gu, Z. (2022). Is the design guidance of color and material for urban buildings a good choice in terms of thermal performance? *Sustainable Cities and Society*, 83, 103927.
- Hoogendoorn, I. (2024). *The contribution of albedo-enhanced houses in The Netherlands to reducing the urban heat island effect* (Doctoral dissertation).
- Katunský, D., Dolníková, E., Dolník, B., & Krajníková, K. (2022). Influence of light reflection from the wall and ceiling due to color changes in the indoor environment of the selected hall. *Applied Sciences*, 12(10), 5154.
- Lakhdari, K., Sriti, L., & Painter, B. (2021). Parametric optimization of daylight, thermal and energy performance of middle school classrooms, case of hot and dry regions. *Building and Environment*, 204, 108173.
- Minah, G., & Nemcsics, A. (2023). Environmental color design. In *Encyclopedia of color science and technology* (pp. 791-799). Cham: Springer International Publishing.
- Mutani, G., & Todeschi, V. (2020). The effects of green roofs on outdoor thermal comfort, urban heat island mitigation and energy savings. *Atmosphere*, 11(2), 123.
- Ozenen, G. (2023). Lighting Sources Used for Interior Design. In *Architectural Interior Lighting* (pp. 37-49). Cham: Springer Nature Switzerland.
- Rawat, M., & Singh, R. N. (2022). A study on the comparative review of cool roof thermal performance in various regions. *Energy and Built Environment*, 3(3), 327-347.
- Rawat, M., & Singh, R. N. (2022). Impact of light-colored paint materials on discomfort in a building for hot-dry climate. *Materials Today: Proceedings*, 52, 998-1005.
- Rogers, A. (2021). *Full spectrum: how the science of color made us modern*. Houghton Mifflin.
- Sahebgalam, S. (2021). *Assessment of the Circadian Stimulus Potential in a Daylit Classroom: A Simulation-based Evaluation of Key Factors to Enhance Daylight-driven Circadian Lighting* (Master's thesis, Kent State University).
- Salam Azad, A., Salman, M., Kaushik, S. C., & Rakshit, D. (2020). Energy saving potential of tubular light pipe system with different colors on internal surfaces. *International Journal of Energy Sector Management*, 14(4), 793-837.
- Sholanke, A., Fadesere, O., & Elendu, D. (2021, March). The role of artificial lighting in architectural design: a literature review. In *IOP Conference Series: Earth and Environmental Science* (Vol. 665, No. 1, p. 012008). IOP Publishing.
- Tekce, I., Ergen, E., & Artan, D. (2020). Structural equation model of occupant satisfaction for evaluating the performance of office buildings. *Arabian journal for science and engineering*, 45(10), 8759-8784.
- Wai, C. Y., Tariq, M. A. U. R., & Muttill, N. (2022). A Systematic Review on the Existing Research, Practices, and Prospects Regarding Urban Green Infrastructure for Thermal Comfort in a High-Density Urban Context. *Water*, 14(16), 2496.
- Wang, J., Liu, S., Meng, X., Gao, W., & Yuan, J. (2021). Application of retro-reflective materials in urban buildings: a comprehensive review. *Energy and Buildings*, 247, 111137.

- Wu, Y., Chen, X., Li, H., Zhang, X., Yan, X., Dong, X., ... & Cao, B. (2022). Influence of thermal and lighting factors on human perception and work performance in simulated underground environment. *Science of The Total Environment*, 828, 154455.
- Yaman, M. (2021). Different facade types and building integration in energy efficient building design strategies. *International Journal of Built Environment and Sustainability*, 8(2), 49-61.
- Yuan, J., Shimazaki, Y., Zhang, R., Masuko, S., & Cao, S. J. (2023). Can retro-reflective materials replace diffuse highly reflective materials for urban buildings' wall to improve outdoor thermal comfort? *Heliyon*, 9(4).
- Zhang, L., & Kim, C. (2023). Chromatics in urban landscapes: Integrating interactive genetic algorithms for sustainable color design in marine cities. *Applied Sciences*, 13(18), 10306.