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Case Studies

# Natural Daylighting for Energy Efficiency Application at Malaysia Exhibition Space: A Conceptual Review

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## Abstract

With the increasing emphasis on sustainability and energy efficiency, integrating natural daylight in museum exhibition centers presents an opportunity to reduce energy consumption while enhancing visitors' experience. This paper investigates the role of natural daylighting as a sustainable design strategy in exhibition space among Malaysian and international standards. It assesses the awareness and implementation of daylighting practices among designers and users. A systematic review from 10 peer researchers summarized the approach to propose the greatest daylighting strategies in exhibition spaces. Findings allocate the favors within broader sustainable architectural practices and design while applying lighting technology. The anticipated outcomes of this study include practical recommendations for architects and exhibition organizers and insights into balancing sustainability and functionality. This research aims to contribute to energy-efficient practices in Malaysian cultural infrastructure, aligning with ecological and cultural objectives.



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## 1. Introduction

The importance of energy efficiency has been widely recognized as a crucial factor in reducing environmental impacts and enhancing sustainability, particularly in buildings designed for public use. Among the various strategies to improve energy efficiency, optimizing natural daylight has gained significant attention due to its potential to reduce reliance on artificial lighting while enhancing the occupants' well-being. Art exhibition centers require a delicate balance between utilizing natural daylight and protecting sensitive art pieces from harmful light exposure.

Malaysia, where art and cultural tourism play a pivotal role, enhances energy efficiency through natural daylight integration, an essential aspect of modern architectural design. Art exhibition centers in Malaysia have seen a rise in interest as part of the state's growing cultural identity and tourism

development. According to Hurlbert et al. [1], the architectural designs of art spaces are increasingly incorporating sustainable practices, including using natural daylight to minimize energy consumption. Furthermore, daylight is not only an energy-saving element but also enhances the visual experience of the displayed art. Shamri et al. [2] noted that controlled daylighting can elevate the aesthetics of art exhibitions while reducing carbon emissions.

Malaysia has tropical weather conditions that dominate, harnessing natural daylight poses challenges such as managing heat gain and glare. Recent studies have shown that integrating advanced daylight control systems, such as smart shading and reflective materials, can mitigate these issues. buildings in tropical regions, including art centers, could achieve up to 40% reduction in lighting energy usage with optimized daylighting systems, further supporting the importance of natural light in sustainable building design [3].

At the same time, careful attention must be paid to preserving artworks. Overexposure to daylight can lead to fading and deterioration of sensitive materials. According to Ismail et al. [4], modern art exhibition centers have begun utilizing specialized glazing and UV filters to ensure that the benefits of daylight are maximized without compromising the integrity of the art displayed. In summary, energy efficiency through natural daylight in art exhibition centers represents an innovative and environmentally responsible approach to design application.

## 2. Objectives

This study aims to evaluate existing standards and benchmarks for lighting levels in exhibition centers. Additionally, the review article seeks to compile, analyze, and summarize sustainable design practices and the application of natural daylighting strategies to achieve energy efficiency.

## 3. Literature Review

Integrating natural daylighting into buildings has gained significant attention as a sustainable architectural strategy. Art exhibition centers, particularly in Malaysia's tropical regions, present challenges and opportunities in effectively utilizing daylight. While daylighting can enhance energy efficiency, it must also ensure the preservation of sensitive artwork. To address these complexities, this literature review explores strategies for optimizing daylight, incorporating energy efficiency principles, regulatory guidelines, and technological advancements.

### 3.1. Natural Daylighting and Energy Efficiency

Daylighting has become a critical component of energy-efficient building design. According to MS 1525:2019 (Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings) [5], optimizing daylight penetration can significantly reduce energy consumption. Escobar (2024) highlights that high-transmittance glazing improves indoor lighting while maintaining the natural spectrum, enhancing both efficiency and occupant well-being. Razak et al. [30] further emphasize that skylight design can optimize daylight penetration, reducing reliance on artificial lighting while maintaining aesthetic appeal.

Research by Razak et al. [3] demonstrates that daylighting strategies tailored for tropical climates can reduce lighting energy consumption by up to 40%. Aderonmu et al. [6] explore using phase change material (PCM) glazing, which enhances thermal stability and minimizes temperature fluctuations, improving energy performance. Lee et al. [7] investigate daylight-concentrating louvers. Combined with LED dimming systems, this results in substantial reductions in lighting energy consumption. These

advancements highlight the growing potential of daylighting technologies in achieving sustainable, climate-responsive energy efficiency.

### 3.2. Standards and Benchmarks of Lighting Levels for Exhibition Centers

Ensuring appropriate lighting levels in exhibition centers is essential for both art preservation and visitor experience. Various international and national standards provide benchmarks for maintaining optimal illuminance levels, balancing visibility, energy efficiency, and artwork protection. According to the Illuminating Engineering Society (IES) and the CIE (International Commission on Illumination), the recommended lighting levels in art exhibition spaces vary based on the sensitivity of artworks:

- Highly sensitive artworks (e.g., watercolors, textiles): 50 lux (maximum)
- Moderately sensitive artworks (e.g., oil paintings, wood sculptures): 150– 200 lux
- Less sensitive materials (e.g., stone, metal sculptures): 300 lux and above

In Malaysia, the MS 1525:2019 Code of Practice on Energy Efficiency and Renewable Energy for Non-Residential Buildings provides guidelines on energy-efficient lighting in buildings, including exhibition spaces. The standard recommends efficient lighting designs incorporating daylight harvesting, automatic controls, and LED technology to reduce energy consumption while ensuring compliance with visual comfort requirements.

This Malaysian Standard is produced to encourage the design, operation, and maintenance of new and existing buildings to reduce energy consumption without constraining creativity in the design, building function, and the comfort or productivity of occupants, as well as cost considerations. The guidance of energy efficiency design demonstrated a good professional judgement to comply with the minimum standard. It encouraged the application of renewable energy to maintain the comfort, health, and safety of occupants in the building. Malaysian Standard (MS1525, 2019) requirements for energy efficiency, such as:

- The requirement of the energy efficiency system
- Minimizing the losses in the electrical power distribution equipment
- Designing a good energy management system

A few general energy efficiency practices for lighting include providing a suitable visual environment within a particular space, such as sufficient and appropriate lighting for performance or a range of tasks and providing the desired appearance and maintaining the illuminance level in the general building area. The recommendation for the average illuminance level for lighting is shown in Table 1.

Additionally, the UNESCO Conservation Guidelines emphasize that prolonged exposure to direct sunlight and UV radiation can cause artworks to fade and degrade. To mitigate these risks, exhibition centers should incorporate UV filtering glazing, controlled daylighting strategies, and dynamic shading systems to regulate natural light exposure. By aligning with these standards and benchmarks, exhibition centers in Malaysia can achieve optimal lighting conditions, ensuring energy efficiency, visual comfort, and artwork protection.

### 3.3. Challenges in Daylighting for Museum Exhibition Space

While daylighting provides energy-saving benefits, its application in exhibition space remains challenging. Excessive sunlight exposure can cause artwork degradation, as UV rays and uncontrolled light levels contribute to fading and deterioration [8], to address these risks, daylighting strategies must comply with international museum lighting standards, such as the CIE 157:2004 Guide for Lighting Museums and Galleries [9], which recommends strict UV filtration and controlled illuminance levels.

Furthermore, tropical climates in Malaysia experience heat gain and glare issues, increasing cooling loads and reducing daylighting efficiency. Kim et al. [10] advocated for smart glazing, automated shading, and reflective materials to balance daylighting with artwork protection. Zhang [11] introduces algorithm-based shading systems that dynamically adjust daylight penetration, balancing natural light, thermal comfort, and energy savings.

Beyond energy efficiency, daylighting enhances exhibition spaces' visual and experiential quality. Xu et al. [12] stated that integrated daylight control systems improve visual comfort, ensuring optimal illumination without compromising art preservation. Al-Obaidi et al. [13] emphasized daylight's role as a design element, shaping spatial perception and influencing visitor experience and emotional well-being. Additionally, daylighting must be aligned with sustainability goals set by Malaysia's Green Building Index (GBI), which encourages passive daylighting strategies and efficient energy use in public buildings. Implementing these strategies ensures that art exhibition centers in Malaysia can achieve an optimal balance between aesthetics, energy savings, and artwork preservation.

**Table 1: Recommendation average illuminance level for lighting [5].**

| Task | Illuminance (LUX) | Example of Applications |
|---|---|---|
| **Lighting for infrequently used areas** | 20 | Minimum service of illuminance, Interior walking, Car park |
| | 100 | Staff changing room, Locker room, Cleaner room, Cloakroom, Lavatories, Entrance hall, Lobbies, Waiting room |
| **Lighting for walking interiors** | 200 | Infrequent reading and writing, General offices, Shops and stores, Reading and writing drawing office |
| | 300-400 | Kitchen, Classroom, Library, Shop/Supermarket/Department store, Museum, Gallery |
| **Localized lighting for exacting tasks** | 500 | Proofreading |
| | 2000 | Detailing and precise work |

## 3.4. Sustainable Design and Application of Natural Daylighting to Obtain Energy Efficiency

The energy challenge has gained prominence today due to potential future shortages and the threat of global warming. Following the signing of the Kyoto Protocol in December 1997, many governments worldwide have pledged to reduce greenhouse gas emissions. Consequently, optimizing energy use has emerged as a central concern in most energy policies. Buildings represent some of the largest consumers of energy. For this reason, Table 2 outlines the design initiatives and implementation of exhibition spaces explored by peer researchers.

The application and adaptation of natural daylighting for energy efficiency are summarized in three categories: (1) design of building elements, (2) energy-saving lighting technology, and (3) materials used.

## 4. Results

Malaysian buildings abide by MS1525:2019 Code of Practice on Energy Efficiency and Renewable Energy for Non-Residential Buildings, which provides guidelines on energy-efficient lighting in buildings, including exhibition spaces. Its purpose is to control the illuminance level in public spaces.

The literature review of the findings reveals that while natural daylighting is widely acknowledged as beneficial, many exhibition centers lack proper strategies for effective implementation. The results highlight several key observations. Firstly, many exhibition centers rely heavily on artificial lighting due to heat gain and glare concerns. While natural daylighting reduces energy consumption, inadequate shading systems and poor window placements often result in overheating, leading to increased cooling costs. Table 2 indicates that eight out of ten researchers find that the case studies favor utilizing the design elements to obtain energy efficiency of natural lighting in museum exhibition spaces. These designs include enhanced external courtyards and internal patios, skylights, window applications, and a solar tube hole light at the dome and the wall. Layout and exhibition space location to be considered too [14].

Secondly, light distribution varies across exhibition spaces, affecting artwork visibility and visitor comfort. Some areas receive excessive sunlight, which can cause sensitive artworks to fade or deteriorate, while others remain underlit. Moreover, implementing sophisticated daylighting controls, including motion sensors, intelligent shading systems, and UV-filtering glass, is still relatively uncommon in most exhibition centers.

Daylighting simulations confirmed that strategic placement of skylights, light shelves, and reflective surfaces can significantly improve light uniformity while minimizing heat gain [8]. Optimized architectural design incorporating these elements can enhance sustainability without compromising artwork preservation.

Overall, the results emphasize the need for tailored daylighting strategies considering climate-specific challenges. Practical solutions such as improved shading devices, optimized window orientations, and automated daylighting controls are recommended to maximize energy efficiency and enhance visitor experience.

## 5. Conclusion

Natural daylighting can enhance energy efficiency and visitors' experience in exhibition centers. However, its successful implementation requires a balanced approach that aligns with regulatory standards such as MS1525:2019, CIE 157:2004, and GBI guidelines. Advances in smart daylighting technologies, such as automated shading and UV filtration, provide promising solutions to climate-specific challenges in regions like Malaysia. By integrating these strategies, the designers can create sustainable, visually appealing exhibition spaces that honor environmental and cultural objectives.

The outcomes of this study include practical recommendations for architects and exhibition organizers and insights into balancing sustainability and functionality. This research aims to contribute to energy-efficient practices in Malaysian cultural infrastructure, aligning with ecological and cultural objectives.

**Table 2: The initiative design and application of natural daylighting at exhibition space.**

| Ref | Authors | Case study | Application | Findings |
|---|---|---|---|---|
| [8] | Dalipi, 2021[a] | ● Exhibition space, museum | ● **Geometric holes allow light** to enter by illuminating the halls and spaces of the museum's dome and walls. | ● Visitors' paths and controlling the natural light temperature without blocking natural light |
| [10] | Kim, 2014[a] | ● Mimesis art museum space | ● **Enhance external courtyards and the internal patios**<br>● Proposed **skylights and windows.** Therefore, more considerations to control the natural light are needed | ● **Control of natural light is needed to secure a** stable lighting environment.<br>● Attention concerning the visitors' circulation, the display of exhibits, and the lighting control |
| [15] | Moreira, 2021[a,b] | ● Exhibition Space | ● **Combining artificial and controlled natural lighting** solutions for museums proves to be a successful approach to improve the quality of the spaces<br>● Apply **LED lights in a sensitive space.** | ● **Identifying the different museum areas**, facilitating the orientation within the center, and the sensitivity of the artifacts. |
| [14] | Chidi & Daminabo, 2022[a,c] | ● Exhibition space, museum | ● **Top-lighting opening in the interior ceiling**<br>● Side and top lighting apertures, all of which are indirect; the windows face the central atrium, which is covered by a glass canopy, and the top-light openings, | ● Only consideration on benefits and considerations of daylight introduction in museum galleries, and types of daylight openings, and connection to the outdoors |
| [16] | Muñoz-González, 2021[b] | Domestic space in historic centers | Strategies consist mainly of the replacement of incandescent or fluorescent lamps with **LED lamps** | Improve people's well-being while reducing energy expenditure on lighting. This article presents a quantitative approach to improving the levels of natural lighting in residential heritage buildings located in historic centers |
| [17] | Sholanke & Oyeyipo, 2023[a,c] | ● Museum exhibition space | ● The analysis showed that using **domes, clerestory windows, atriums, light tubes, and anti-solar glass/windows was the most adequate daylighting feature** for daylighting designs and energy efficiency optimization. | ● Explores various strategies and techniques on how daylighting can be achieved in the museum spaces |
| [18] | Marzouk *et al.*, 2020[a,c] | ● Historical building | ● The parametric design provides multiple design options for skylight, which target performance criteria for natural daylight | ● Implemented a parametric configuration approach to **redesign the skylight**. |
| [6] | Aderonmu *et al.*, 2019[a,c] | ● Museum space | ● Application of **domes, clerestory windows, atriums, light tubes, and anti-solar glass/windows** was considered to be the most adequate daylighting features sufficient for daylighting designs and energy efficiency optimization | ● Showed that there are parametric energy design indices in the existing architectural designs that apply in forms, spaces, materials, techniques, installation, and strategies to museums in the tropical climatic region |
| [19] | Shahparnia *et al.*, 2020[a,b,c] | ● Museum exhibition space | ● Natural lighting systems widely used in museums show that the **photovoltaic** systems are the most appropriate ones for natural lighting | ● Visual indicators of ergonomic lighting based on high-quality natural light provide the desirable lighting in the museums. |

| | | | | |
|---|---|---|---|---|
| | | | in the museum, followed by **light shield, light pipe, and light shelf** | ● Combining photovoltaic shades with light shields can optimally distribute the light while controlling glare, luminance, shading, and contrast in museums of artworks |
| [12] | Xu *et al.*, 2021[c] | ● Museum Exhibition space-China | ● The **intelligent motion capture lighting** system is designed to apply, ensure the exhibition experience, and reduce the unnecessary exposure of museum exhibits.<br>● Apply natural lighting when the visitors are unattended. | ● Motion capture has great potential in game animation, film, and television animation, virtual image, and other fields. However, in the current commonly used motion capture schemes, the cost of equipment is very high, and the implementation site is limited |

**a**-Design elements **b**-lighting energy saving technology **c**-materials savvy

## Declaration of Conflict of Interest

The authors declared no conflict of interest with any other party on the publication of the current work.

## References

[1] A. Hurlbert, and C. Cuttle, New Museum Lighting for People and Paintings. LEUKOS 16 (2019) 1–5. https://doi.org/10.1080/15502724.2019.1676019

[2] S.L. Shamri, E. Mohd Husini, F. Arabi, A. Abdul Manaf, M. Mat Idris, and J. Jamaludin, Strategies in Improving the Building Efficiency and Daylighting: A Case Study of Green Building, Planning Malaysia 20 (2022) 99-109. https://doi.org/10.21837/pm.v20i21.1095

[3] M.S. Bakry, M. Hamdy, A. Mohamed, and K. Elsayed, Energy Saving Potential in Open Museum Spaces: A Comparative Hygrothermal Microclimates Analysis. Building and Environment 225 (2022) 109639. https://doi.org/10.1016/j.buildenv.2022.109639

[4] M. Mostafa R. Ismail, A. Nessim, and F. Fathy, Daylighting and Energy Consumption in Museums and Bridging the Gap by Multi-Objective Optimization. Ain Shams Engineering Journal 15 (2024) 102944. https://doi.org/10.1016/j.asej.2024.102944

[5] Malaysian Standard. Code Of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (First Revision).

[6] P. Aderonmu, A. Adesipo, E. Erebor, A. Adeniji, and O. Ediae, Assessment of Daylighting Designs in the Selected Museums of South-West Nigeria: A Focus on The Integrated Relevant Energy Efficiency Features. IOP Conference Series: Materials Science and Engineering 640 (2019) 012034. https://doi.org/10.1088/1757-899x/640/1/012034

[7] P. Wargocki, J.A. Porras-Salazar, S. Contreras-Espinoza, and W. Bahnfleth, The Relationships between Classroom Air Quality and Children's Performance in School. Building and Environment 173 (2020) 106749. https://doi.org/10.1016/j.buildenv.2020.106749

[8] S. Dalipi, Natural Lighting of Museums, UBT International Conference, 2021. Retrieved from: https://knowledgecenter.ubt-uni.net/conference/2021UBTIC/all-events/9

[9] CIE (Commission Internationale de l'Eclairage), Control of Damage to Museum Objects by Optical Radiation, Standard CIE 157, 2004, Paris. Retrieved from: https://cie.co.at/publications/control-damage-museum-objects-optical-radiation

[10] C.S. Kim, An Evaluation of Light Distribution in the Exhibition Areas of the Mimesis Art Museum Designed by Alvaro Siza. Journal of Building Construction and Planning Research 2(4) (2014) 227–243. https://doi.org/10.4236/jbcpr.2014.24021

[11] P. Sharafi, M. Rashidi, M. Alembagheri, and A. Bigdeli, System Identification of a Volumetric Steel Modular Frame Using Experimental and Numerical Vibration Analysis, Journal of Architectural Engineering 27(4) (2021). https://doi.org/10.1061/(asce)ae.1943-5568.0000498

[12] L. Xu, S. Yan, Z. Chen, X. Chen, Design of the Museum Interactive Lighting System Based on the Digital Twin Technology. Scientific Programming 2021 (2021) 1–8. https://doi.org/10.1155/2021/4824417

[13] W. Lu, Dynamic Shading and Glazing Technologies: Improve Energy, Visual, and Thermal Performance. Energy and Built Environment 5 (2024) 211–229. https://doi.org/10.1016/j.enbenv.2022.09.004

[14] E.C. Chidi, and F.F.O. Daminabo, Effective Use of Natural Lighting Strategy in Museum. Global Scientific Journal 10(4) (2022) 1247-1262.

[15] S. Moreira, Beyond Artificial Lighting: Museums Exploring the Benefits of Daylight [Para além da iluminação artificial: museus que exploram os benefícios da luz natural] Retrieved from: https://www.archdaily.com/960558/beyond-artificial-lighting-museums-exploring-the-benefits-of-daylight (accessed 26 Feb 2025).

[16] C. Muñoz-González, J. Ruiz-Jaramillo, T. Cuerdo-Vilches, M.D. Joyanes-Díaz, L. Montiel Vega, V. Cano-Martos, and M.Á. Navas-Martín, Natural Lighting in Historic Houses during Times of Pandemic. The Case of Housing in the Mediterranean Climate. International Journal of Environmental Research and Public Health 18 (2021) 7264. https://doi.org/10.3390/ijerph18147264

[17] A.B. Sholanke, and F.J. Oyeyipo, Appraisal of Lighting Strategies for Achieving Environmental Sustainability in Selected Art Museums and Galleries in Nigeria. Civil Engineering and Architecture 11 (2023) 3811–3825. https://doi.org/10.13189/cea.2023.110641

[18] M. Marzouk, M. ElSharkawy, and A. Eissa, Optimizing Thermal and Visual Efficiency using Parametric Configuration of Skylights in Heritage Buildings. Journal of Building Engineering 31 (2020) 101385. https://doi.org/10.1016/j.jobe.2020.101385

[19] M. Shahparnia, and N. Nikghadam, Ergonomic Natural-Solar Lighting Systems in Museum of Artworks. Armanshahr Architecture & Urban Development 12(29) (2020) 65-80. https://doi.org/10.22034/aaud.2020.102366.