PLANNING MALAYSIA:
Journal of the Malaysian Institute of Planners
VOLUME 20 ISSUE 2 (2022), Page 99 – 109

STRATEGIES IN IMPROVING THE BUILDING EFFICIENCY AND DAYLIGHTING: A CASE STUDY OF GREEN BUILDING

Shaza Liyana Shamri[1], Elina Mohd Husini[2], Fadli Arabi[3], Azhani Abdul Manaf[4], Madihah Mat Idris[5], Juliza Jamaludin[6]

[1,2,3,4,5,6]*Faculty of Engineering and Built Environment*
UNIVERSITI SAINS ISLAM MALAYSIA

Abstract

Malaysia is one of the rising countries with the highest energy consumption rate, which is attributable to strong economic development in the residential and commercial sectors that consume approximately half of the total electricity generated. Several criteria have been implemented in Malaysia to develop efficient building design, such as the Green Building Index (GBI) and Passive Daylighting Strategies. The study aims to investigate passive daylighting solutions for different building orientations and facade materials to measure energy efficiency through building designs. Buildings are a variable that contributes to growing energy consumption resulting from population increase and climate change. The building facade is a factor that could control the indoor environment, which affects the energy consumption in buildings. A case study determined the elements that maintain building efficiency and electric savings by examining two buildings certified by the Green Building Platinum and the Ministry of Finance (MoF). Low consideration of Passive Daylighting Strategies in building designs allows direct sunshine and increases the use of air conditioning to maintain the room at a comfortable temperature.

***Keywords**:* Facades, Climate, energy efficiency, daylighting, passive strategies

[1] PhD Student at University Sains Islam Malaysia Email: shazaliyana21@raudah.usim.edu.my

INTRODUCTION

Malaysia is a tropical Southeast Asian country near the equator, located between the latitudes of 1° and 7° north and the longitudes of 100° and 119.5° east. Each month, Malaysia is exposed to approximately 400 to 600 Mj/m2 of radiation (Aziah & Ariffin, 2004). The average temperature in Malaysia is between 24.5° to 28.5° Celsius, which is higher than the advised range by the Ministry of Energy, Telecoms, and Posts (Zain, 2008). Most studies proposed that the comfortable air temperature in Malaysia is around 25° C.

Numerous studies explore the factors impacting energy efficiency with population, climate change, and economic growth. Climate change is considered the most significant global challenge. The buildings in Malaysia emit the greenhouse effect that contributes over 40% of carbon gases (Zakaria et al., 2021). The condition is detrimental to the environment, which affects climate change. Thus, various sustainable building assessment tools have been established since the late 20th century (E. Papargyropoulouet et al., 2012).

The WHL energy mentioned the basic energy efficiency principles, which balances between maximising heat gain to minimising heat loss. Energy efficiency also depends on the size of space, orientation, the building material, and the thermal storage mass (Passive design strategies, metal architecture, 2021)

The Malaysian population is increasing, which leads to an increase in energy consumption. Modeste et al. (2014) stated that energy are the most significant resource in developing countries and the rapidly growing world population. Han et al. (2021) predicted that urbanisation affects energy use on several factors, such as the population and economic development. Meanwhile, Kavousian et al. (2014) mentioned four major factors that influence the building energy consumption and occupants' behaviour based on the location, weather, physical characteristics, and appliance usage.

Buildings utilised approximately 40% of the total world energy in 2015, and the figure is predicted to increase to at least 50% by 2030 based on current trends. Numerous aspects influence the energy efficiency of a structure. Daylighting is the controlled intake of natural light, direct sunlight, and diffused skylight into a building to reduce electric lighting and conserve energy (Gregg D Ander, 2016). The building efficiency is also determined by the material used to construct the building. In a tropical setting, the insulating wall lowers energy consumption by minimising the peak heat load from the tropical climate (Y.H.Lee et al., 2021).

The passive daylighting strategies in the study emphasise the building orientation and the material of the facade building. A vital element includes the design that exposes the building to sunlight to minimise the heat load. A building with an excessive amount of heat and direct sunlight could encounter issues in controlling and maintaining the internal building temperature, thus affecting the building efficiency and electricity usage. The study discussed the material with an optimum U-value and K-value that optimally controls the interior building temperature. Additionally, the study investigated the major passive daylighting strategies with GBI certified buildings for building efficiency.

ENERGY EFFICIENCY

Building efficiency is defined as a building that can minimise the energy demand for heating and cooling (ISOVER, 2021). The energy efficiency concept is to generate and utilise energy as efficiently as possible. The New World Research Institute (WRI) examines the significant role of building and shaping sustainable cities of the future and developing the communities. Natural daylighting has always been a topic of improvement due to the availability of cheap electricity and to control the illumination level due to artificial lighting.

The ISOVER (2021) mentioned thermal insulation of components which involve cost and is widely available as energy-saving components. Thermal insulation components depend on the building material, consisting of a K-value and U-value that determine the heat received into the building. The term 'K-value' refers to the thermal conductivity of a material. The K-value is also known as the rate of the constant heat flow via a unit area of a homogeneous material in the perpendicular direction (Gordon H. Hart, 2009). Additionally, the material thickness determines the K-value. Meanwhile, the 'U-value' refers to thermal transmittance. Heat transmission defines the area of material construction and the boundary air films (Gordon H. Hart, 2009). The lower the number of the U-value and the higher the K-value, the better the energy efficiency in warm climates, such as in Malaysia.

Building materials are categorised into two: heavyweight and lightweight. Concrete, masonry walls, and stone finishes are heavyweight materials with a high density and heat capacity (Saleh et al., 2017). In warmer areas, lightweight materials, such as timber, steel framing, insulated panels, prefabricated items, and polystyrene construction products respond instantly to temperature fluctuations and cool rapidly overnight (Rhys Kelly UDIA WA President, 2017).

DAYLIGHTING AND ENERGY EFFICIENCY

Daylight is the use of windows and skylights to attract natural lighting and temperature regulation, which saves cost and minimises energy consumption. Daylight reduces the use of artificial lighting where the study proved that daylight reduces the cooling load and demand of building energy (D.H.W. Li, 2005). Artificial lighting produces 70 to 100lm/Watt and daylight has a higher luminous efficacy of 110 to 130lm/watt, hence reducing the cooling load (P.J. Littefair, 1985). Yu and Su (2015) found that daylight harvesting can save energy in lighting by 20 to 87%, assessed through simulation and algorithm calculations. Moreover, Kamaruzzaman et al. evaluated the tropical context at the Klang

District, where the office building had average lighting consumption and saved approximately 37% from daylighting.

PASSIVE DAYLIGHTING STRATEGIES

Passive Daylighting Strategies are measures that do not require using any special mechanical equipment or energy source in the building design. The solutions are described as a component that accumulates natural light and reflects the light into dark areas to increase the distribution of daylight inside the building. Several studies have proven that daylighting is the most efficient way to achieve building efficiency. For instance, Surendran mentioned that passive daylight strategies in tropical buildings reduced the impact of the building environment. Furthermore, daylighting provides significant health and wellness benefits to the users. Natural light improves users' performance, healing, productivity, and satisfaction, which concern the four major factors that influence energy consumption.

The HMC Architect news listed various criteria of the passive daylighting system, such as building orientation, window type, skylight, clerestories, external shading system, light shelves, solar tubes, light wall colours, Parametric modelling, daylight simulation, and artificial intelligence (AI). Meanwhile, A. Zain- Ahmed examined tropical buildings in Malaysia and discovered four significant types of passive daylighting strategies that should be emphasised: the orientation of the building, shading elements, window to wall ratio, and window type. Hence, the findings demonstrated that a minimum of 10% savings could be made from simple daylighting strategies.

METHODOLOGY

The study conducted a comparative analysis of three case study methods that described the building orientation and U-value of facade that control the temperature inside the building, which contributes to energy savings. Two of the selected buildings were certified by green building while the other building encountered an issue with energy management. The Wall Simplified Energy Index table in the passive design guideline is the base line for the comparison

RESULT AND DISCUSSION

The three offices were compared to analyse the passive strategies used to cater to the climate change and electric usage. Table 1 compares the passive strategies on the MoF, the Energy Commission Building (ECB), and the Public Work Department Block G (PWD).

Table 1: Description and difference of the selected building

Description/ Building	**Location**	**Award**	**Material**	**Daylight Strategies**	**Energy Savings**	**Scores in Green Building Index**
Ministry of Finance (MoF)	Putrajaya	-	-Full reinforced concrete -Green a front and back facades -landscape are (60:40)	-Shading device and blind (75%) -WWR (65%)	(0.5%) due to office management setup	-
Energy Commission Building (ECB)	Putrajaya	Multi-award-winning green building (GBI Platinum and Green Mark Platinum in non-residential category.	-double glazing glass	-Building Orientation -light shelf and atrium - WWR (50%)	52.8%	88%
Public Work Department Block G (PWD)	Kuala Lumpur	GBI platinum	- glass and concrete deep partition	-Building Orientation -horizontal Louvers & Interior Partition -Windows type -WWR (90%)	40.9%	86%

Mohd Nasrun's (2014) study on the MoF Putrajaya suggested that the building orientation and material were the key factors that need to be considered in controlling the heat consumption in buildings. The windows in the building were designed facing the east and west, which brings in direct sunlight in the day and evening. Furthermore, the office management set up by the occupants in the building holds a crucial role in saving electricity and supporting building efficiency.

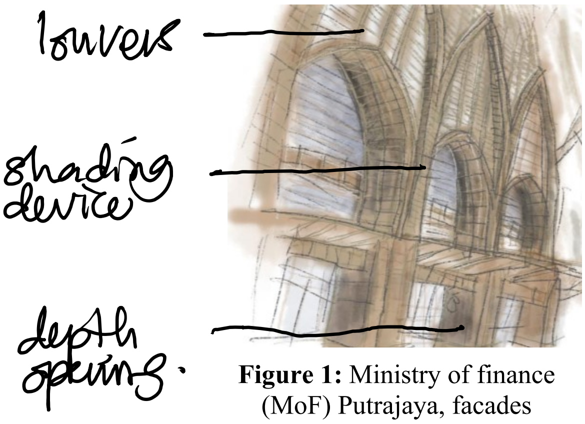

Figure 1: Ministry of finance (MoF) Putrajaya, facades
Source: Author,2021

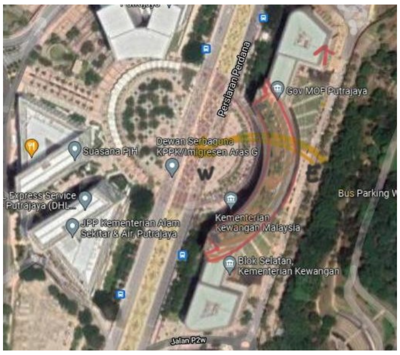

Figure 2: Orientation of MoF building
Source: Google map

Figure 1 depicts the facades of the MoF comprising louvres, shading devices, and depth at the opening as passive design strategies to ensure the building efficiency, but the direction of the window and door facades are facing the East and West increases heat gain and depending on the office management operation.

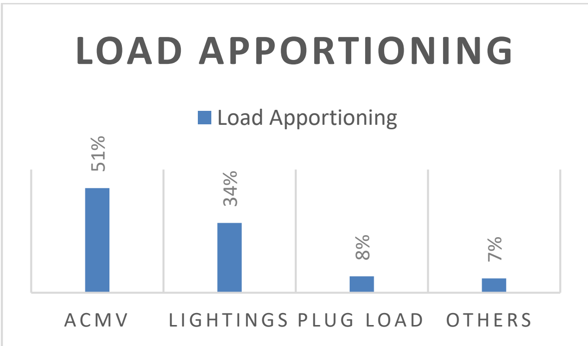

Figure 3: Load Apportioning of the building
Source: Energy management, Case study on Malaysian Government Office Building

Figure 3 illustrates that the largest load apportioning in the building is the Air condition and Mechanical Ventilation System (ACMV) at 51% due to the indoor temperature increasing during the daytime. The MoF building was reported as hot during the daytime, which produced an uncomfortable environment during working hours. The MoF building occupants proposed the management to control the electrical usage of the building through the management programme that saved over 0.5% of electricity.

Figure 4: Diamond building, Energy Commission Building (ECB)
Source: Magazine High Performing Building, Nov 2014

Figure 4 illustrates the second case study on the ECB, a multi-award-winning green building (GBI Platinum and Green Mark Platinum) in the non-residential category. The building shape is unique to prevent direct sunlight and allow the light to enter the building through the light reflecting from the pavement and landscape, as displayed in Figure 5. The design affects the building efficiency by controlling the heat gain of the building facade during the daytime and reducing the use of artificial light and air-conditioning in the building.

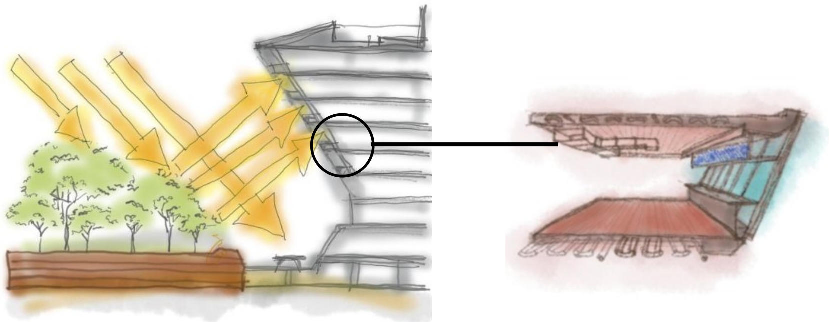

Figure 5: Reflectance of light to avoid direct sunlight

Figure 6: Public Work Department Block G (PWD)
Source: 2017, KCJ Engineering SDN. BHD.

The ECB and PWD were platinum certified by GBI according to Nikpour et al. (2017). The ECB building emphasised the daylighting strategies, which outlined the light shelf and atrium that reflect the diffuse daylighting into space. The ECB acquired an 88% score in GBI, which held the platinum rating of over 86% points. The opening of building orientation occupied the South Segment. Additionally, the building orientation shading system controlled the heat received in the building and enabled electricity savings.

Figure 7: Orientation of ECB and PWD building respectively
Source: Google map

Figure 7 demonstrates that the building corner is located at the east and west sides, designed to receive less impact from direct sunlight. Thus, the design decreases the surface area of the building facing the direct sunlight during the daytime. The condition lowers heat gain in the building and minimises electricity usage of the building during the daytime.

Gene-Harn Lim (2017) discovered that most ECB and PWD occupants preferred daylight in their office working space. The results of artificial lighting suggested that the PWD occupants usually switch off the lighting in the morning (8.30 am to 12.00 pm) and afternoon (12.00 pm to 4.00 pm) due to sufficient daylight from the east-facing windows. The study revealed that ECB and PWD saved energy by 40.9% and 52.8%, respectively.

ENERGY INDEX BASED ON U-VALUE

Various factors control the internal heat of a building that impact building efficiency, such as the material of the building facades to save electricity. The material type of the building facade consists of different U-values that affect the building heat consumption.

The energy simulation performed in the guidebook passive design in the wall insulation section derived an estimation of energy and peak load reduction. The U-value in the creation index goal evaluated the energy savings produced by building material based on Malaysian climate zones. The Wall Simplified Energy Index table lists the U-value as follows:

Table 2: Energy (Electricity) reduction per wall area per U-value reduction for range of based Load scenario

Description	**ASHRAE U-value**	**Wall simplified Energy Index (kWh/year of m2 of wall area)**		
		High Night-time Parasit Load	Mid Night-time Parasit Load	Low Night-time Parasit Load
Steel Sheet, 10mm	6.68	77	55	53
Concrete Wall, 100mm	3.40	55	32	28
Brick Wall,115mm	2.82	52	30	25
Brick Wall, 220mm	2.16	50	27	22
Double Brick Wall with 50mm cavity, 300 mm	1.42	48	25	20
Autoclave Lightweight Concrete, 100mm	1.25	47	24	18
Autoclave Lightweight Concrete, 150mm	0.94	45	22	17
Autoclave Lightweight Concrete, 200mm	0.75	45	22	16
Steel/Aluminium Composite Wall with 75mm insulation	0.38	45	21	15

Source: Guideline for Passive Design by CK Tang and Nic Chin

The table demonstrates that the MoF building was constructed using reinforced concrete as the building material held a high U-value. Meanwhile, the ECB and PWD buildings were covered by double-glazed glasses that are tinted, which tends to hold a lower U-value, hence producing less heat conduction through glazing (Green Quarter, 2018).

CONCLUSION

Based on the case study of three buildings, designers must consider building passive methods early in the design process. Moreover, the building orientation significantly impacts the ability to save electricity. The MoF building lacks building orientation, the building encounters energy management challenges and save only 0.5% of electricity through the office management setup. The result demonstrated the necessity of construction orientations in specific locations. The type of material used on the building facade is also critical in achieving energy efficiency.

The study discovered that building orientation, passive daylight methods, and building material are the most important factors in controlling heat consumption in buildings. Less heat usage improves building efficiency while conserving power.

ACKNOWLEDGEMENTS

This paper was supported by research Fundamental Research Grant Scheme (FRGS/1/2020/SSI02/USIM/02/1) and (PPPI/FLAGSHIP/FKAB/USIM/18021).

REFERENCES

Aziah, N., and M. Ariffin. "The effect of orientation on energy efficiency potential for terraced housing in Malaysia." no. November (2004): 10-12.

A. Zain-Ahmed, “Renewable energy, buildings and the fuel crisis,” *International Conference on Construction and Building Technology*, Kuala Lumpur, 2008, pp. 13-24.

Elina Mohd Husini, Raja Nur Syaheeza Raja Md Yazit, FAdli Arabi, Wan Norisma Wan Ismail, Nor Haslina Jaafar. “Light, daylighting and fluctuation of illuminance level in office buildings”, *IOP Conference Series: Material Science and Engineering*, 2018.

Abdul Latif, S. N., Chiong, M. S., Rajoo, S., Takada, A., Chun, Y. Y., Tahara, K., & Ikegami, Y. (2021). The Trend and Status of Energy Resources and Greenhouse Gas Emissions in the Malaysia Power Generation Mix. *Energies*, 14(8), 2200.

Aldhshan, S. R., Abdul Maulud, K. N., Wan Mohd Jaafar, W. S., Karim, O. A., & Pradhan, B. (2021). Energy consumption and spatial assessment of renewable energy penetration and building energy efficiency in Malaysia: A review. *Sustainability*, 13(16), 9244.

D.H.W. Li, J.C. Lam, S.L. Wong Daylighting, and its effects on peak load determination Energy, 30 (2005), pp. 1817-1831, 10.1016/j.energy.2004.09.009

E. Papargyropoulou, R. Padfield, O. Harrison, C. Preece The rise of sustainability services for the built environment in Malaysia *Sustain. Cities Soc.*, 5 (2012), pp. 44-51

Lee, Y.H.; Amran, M.; Lee, Y.Y.; Kueh, A.B.H.; Kiew, S.F.; Fediuk, R.; Vatin, N.; Vasilev, Y. Thermal Behavior and Energy Efficiency of Modified Concretes in the Tropical Climate: A Systemic Review. *Sustainability* 2021, 13, 11957. https://doi.org/10.3390/ su132111957

Gene-Harn Lim, Michael Barry Hirning, Nila Keumala, Norafida Ab. Ghafar. “Daylight performance and users’ visual appraisal for green building office in Malaysia”, *Energy Building*, 2017.

Hassan, J. S., Zin, R. M., Abd Majid, M. Z., Balubaid, S., & Hainin, M. R. (2014). Building energy consumption in Malaysia: An overview. *Jurnal Teknologi*, 70(7).
Layke, J., Mackres, E., Liu, S., Aden, N., Becqué, R., Graham, P., ... & Mazur-Stommen, S. (2016). *Accelerating Building Efficiency*.
Lim, G. H., Hirning, M. B., Keumala, N., & Ghafar, N. A. (2017). Daylight performance and users' visual appraisal for green building offices in Malaysia. *Energy and Buildings*, 141, 175-185.
Nawi, M. N. M., Baharum, F., Rajemi, M. F., Ibrahim, J. A., & Tahir, M. Z. Energy Management: A Case Study on the Malaysian Government Office Building. (2014)
Ng, K. M., Adam, N. M., Inayatullah, O., & Ab Kadir, M. Z. A. (2014). Assessment of solar radiation on diversely oriented surfaces and optimum tilts for solar absorbers in Malaysian tropical latitude. *International Journal of Energy and Environmental Engineering*, 5(1), 1-13.
P.J. Littlefair The luminous efficacy of daylight: a review Light. Res. Technol., 17 (1985), pp. 162-182 abstract http://lrt.sagepub.com/content/17/4/162
S. N. Kamaruzzaman and R. Sulaiman, "Energy audit of old buildings in Malaysia: An indicative survey on electricity services performance. http://www.tnb.com.my/residential/pricing-and-tariff.html (accessed 14 November 2021).
Tang, C. K., & Chin, N. (2013). Building energy efficiency technical guideline for passive design. *Public Works Department Malaysia*, Kuala Lumpur.
Rhys Kelly UIDA WA President, The Benefits of Lightweight Construction. The West Australian., *Real Estate*. (2017), Live2017.07.03.11.28am
X. Yu, Y. Su Daylight availability assessment and its potential energy saving estimation – a literature review *Renew. Sustain. Energy Rev*., 52 (2015), pp. 494-503, 10.1016/j.rser.2015.07.142
Saleh, P.H., Schiano-Phan, R. and Gleeson, C. 2017. What heavy weight buildings in hot climates can tell us about their thermal performance. Design to Thrive. Edinburgh 02 - 05 Jul 2017 NCEUB 2017.
Shaban R.S. Aldhshan, Khairul Nizam Abdul Maulud, Wan Shafrina Wan Mohd Jaafar, Othman A. Karim, Biswajeet Pradhan. "Energy Consumption ans Spatial Assessment of Renewable Energy Penetration and Building Energy Efficiency in Malaysia: A Review", *Sustainability*, 2021.

Received: 20th April 2021. Accepted: 15th June 2022

