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Energy Efficiency Improvement and Strategies in Malaysian Office Buildings (Tropical Climate): A Review

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ABSTRACT

Buildings are one of the highest energy consumption contributors in the construction sector in Malaysia. Some parameters are acknowledged as the factors that influence the efficiency of building energy, including climate conditions, location and type of buildings. Optimizing the energy efficiency of buildings is a more economical strategy to reduce energy consumption, especially for tropical climates, and Malaysia naturally has plenty of sunlight and consistency throughout the year. Therefore, this paper discusses Malaysia different building designs and policies to improve energy consumption and efficiency of office buildings in Malaysia. In addition, the limitations encountered and the initiatives implemented by the Malaysian government in improving energy usage in the office building are also included. This review is expected to provide a framework and explanation that can be used as a guide to identify which approach is most appropriate to help optimize energy efficiency for buildings in developing and tropical countries such as Malaysia.

1. Introduction

Buildings have been identified as the largest energy consumers in the world. The percentages vary from country to country, but in general, buildings are responsible for about 30%–45% of the global energy demand [1]. Building energy consumption has also been identified as one of the major contributors to carbon dioxide and greenhouse gas emissions [2]. In fact, the greenhouse gas emissions in existing buildings in Malaysia have contributed more than 40% of carbon gas to the environment [3]. In developing countries, 20% to 40% of total energy consumption is contributed by residential and commercial buildings. As the population increases, building services, comfort levels, and time spent indoors also increases, thus causing an increase in energy demand. For this reason, improvement of energy efficiency in buildings is a high priority for developing countries including Malaysia. Since the building sub-sector consumes almost half of the total energy, energy efficiency plays an important role in reducing energy consumption and related emissions released into the

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atmosphere [4]. Malaysia generated around 169 billion kilowatt-hours [5] of electricity in 2018, which is an increase of 42% from ten years before. The total electricity use in Malaysian buildings varies depending on building envelope design, HVAC (Heating, Ventilation and Air Conditioning) system efficiency, types of lights used and their efficiency, type of equipment inside the building and building operations and maintenance. Due to the climate condition is generally hot and humid throughout the year, no heating system is used in any of the buildings in Malaysia.

Malaysia is a tropical country located in Southeast Asia, near the equator which, has a daily humid climate and is hot throughout the entire year. One of the factors that cause temperature rise is climate change. The environment and climate have a major effect on building's energy consumption and as a result, energy conscious design requires an understanding of the local climate [6]. Malaysia also has multiple sources of renewable energy such as biomass, solar, hydro, municipal solid waste and wind [7]. Malaysia can overcome the energy shortage by designing more suitable buildings for the hot and tropical climate and building designers also need to find ways to channel the available wind, breeze and sunlight to increase the comfort level inside the building.

This work aims to review the current scenario on building energy in Malaysia and discuss on energy consumption, energy efficiency, government energy programs and their achievement, and the issue of increasing energy consumption in the building sector. The information on building energy in Malaysia is quite scattered in the literature, lacking systematic links and some technical details on the strategies. Hence, this paper will portray various aspects that are useful for the research community, practitioners, and stakeholders to get comprehensive knowledge and a deeper understanding of Malaysian building energy consumption and ways to improve energy efficiency. This study also indicates there are a number of efforts made by Malaysia to reduce energy usage in line with the global goal.

2. Energy Policies

Over the years, the Malaysian government has formulated a number of policies and programs to secure long-term energy supply to fulfil the energy needs. Petroleum Development Act (1974) and National Petroleum Policy (1975) are among the earliest policies set in Malaysia regarding energy consumption but not involving energy efficiency. Rapid economic growth in the 70s especially the development of the manufacturing sector as well as industrial development, especially the development of power intensive industries such as steel, petrochemicals and cement, resulted in energy demand increasing by 13.5% per annum from 1971 to 1975 (Economic Planning Unit, 1975). Therefore, an adequate electricity supply is very important to meet the demand of this industry to ensure that the economy continues to grow and stabled. Thus, the first National Energy Policy (1979) was introduced [8]. In National Energy Policy (1979), three main objectives have been underlined. The first is to ensure the provision of adequate, secure and cost-effective energy supply. Then, the second one is to promote efficient energy utilization and eliminate wasteful and non-productive patterns of energy consumption. Lastly, to minimize negative impacts on energy production, transportation and consumption on the environment. This policy leads to increased energy efficiency and national conservation to ensure productive energy use while minimizing waste for sustainable development [9]. After the introduction of National Energy Policy (1979), several energy policies were introduced i.e., National Depletion Policy (1980), Four Fuel Diversification Policy (1981), Fifth Fuel Policy (2000), Biofuel Policy (2006), National Energy Policy and Action Plan (2010) and National Renewable Energy Policy (2011). The mentioned policies were generally concerned with the depleting fossil fuels and energy security and did not mention anything on energy efficiency. The energy efficiency agenda was first set in the National Energy Policy (1979). The energy efficiency is

playing an important role to ensure the energy usage is optimum and this also mentioned in the 7th Malaysian Plan (1996-2000), 8th Malaysian Plan (2001-2005) and 9th Malaysian Plan (2006-2010) with more emphasis on the industrial and commercial sectors. The Fifth Fuel Policy in 2000 led to the development of renewable energy in Malaysia. As the energy efficiency program did not achieve the goal at that time, the government has developed the National Energy Efficiency Master Plan (NEEMP) in the 10th Malaysia Plan (2011-2015) [8]. Energy efficiency improvement initiatives began under the 11th Malaysia Plan [10].

In spite of not fully achieve the goal, these policies however change the country economy. Thus, necessary amendment must be made to improve the current policy. Not just that, if there are new policies and strategies, they need to be carefully studied before being implemented. This action is necessary because policies do not only affect the energy efficiency goal but also have an impact on the national economy, where bad policies and strategies may destabilize the country's economy.

3. Energy Efficiency Programs

Energy efficiency programs have started in 2000, where one of the first initiatives was the Malaysian Government and United Nations Development Program (UNDP) - Global Environment Facility (GEF) project. This project is called the Malaysia Industrial Energy Efficiency Improvement Project (MIEEIP), which aims to provide a clear understanding and prudent use of energy efficiency practice to the industry. Starting 2014, the government launched Energy Efficiency Challenge in Malaysian schools and declared the program as a national event. In this program the school is required to take proactive measures to reduce their school's electricity consumption over 6 months. Consequently, the energy consumption at school is effectively reduced. In addition, University Science Malaysia's Centre for Education and Training in Renewable Energy and Energy Efficiency (CETREE) is actively involved in creating awareness of energy efficiency and usage of renewable energy among the end-users [4].

Then, Net Energy Metering (NEM) scheme was launching in 2016 under National Energy Efficiency Action Plan (NEEAP) to encourage the use of renewable energy along with reduction in energy consumption [11]. This program was then continued to NEM 2.0 (2019) and NEM 3.0 (2021). In 2019, in line with government initiatives, the national utility company in Malaysia, Tenaga Nasional Bhd (TNB), launched the Energy Efficiency campaign to educate the Malaysian society on the importance of environmental sustainability through energy conservation [12]. For instance, the implementation of the Sustainability Achieved via Energy Efficiency (SAVE) Program (2011-2013) successfully reduced energy consumption by 306.9-gigawatt hour (GWh). This program aims to reduce electricity consumption by increasing the supplier of energy-efficient electrical appliances in the market and spread public awareness to support this program by purchasing energy efficient products.

The effectiveness of the SAVE program makes it a continuously implemented until now (2022) and this was acknowledged by the Minister of Energy and Natural Resources Malaysia, Datuk Seri Takiyuddin Hassan [13]. The program, which started in 2011, now also encouraged consumers to buy locally made electrical appliances or those manufactured in Malaysia and obtain Standard and Industrial Research Institute of Malaysia (SIRIM) certification or equivalent. Along with offering rebates to consumers, the SAVE program also able to increase the level of purchasing energy efficient electrical product thus encouraging the economic growth of post-pandemic countries. As of September 30th 2021, a total of 1,157 shopkeepers and retailers nationwide had registered to participate in the SAVE program and 90,835 consumers had applied for the e-rebate redemption [14]. As stated by Sustainable Energy Development Authority Malaysia (SEDA) [11], the implementation of SAVE 3.0 is expected to provide energy savings of 153 gigawatt joules (GWj) a year which is

equivalent to RM 60.45 million [14]. Additionally, the plan also includes the strategy in terms of the regulation framework, which permitted the minister to promote electricity efficiency under the Malaysian law, Electricity Supply Act 1990 (Act 447) Section 23A, 23B & 23C (Energy Commission Malaysia). Through energy audits, it is proven that energy savings of around 10% can be obtained at low price or at no cost, by only implementing best practices and avoiding wastage of electricity in buildings. In fact, the Malaysian government has audited several buildings that will be refurbish into energy efficient facilities and have shown an energy reduction of around 20% with just the installation strategy [15].

4. Building Design

The Malaysian government started promoting energy efficiency in government buildings through the demonstration of Low Energy Office (LEO) Building and Diamond building (Figure 1). Green Building Index (GBI) is Malaysian green building rating system that is used to rate the buildings according to energy efficiency elements to promote green building design specifically for the Malaysian tropical climate [16-17]. The criteria evaluated in GBI are indoor environment quality, sustainable site planning, materials and resources, water efficiency and innovation.

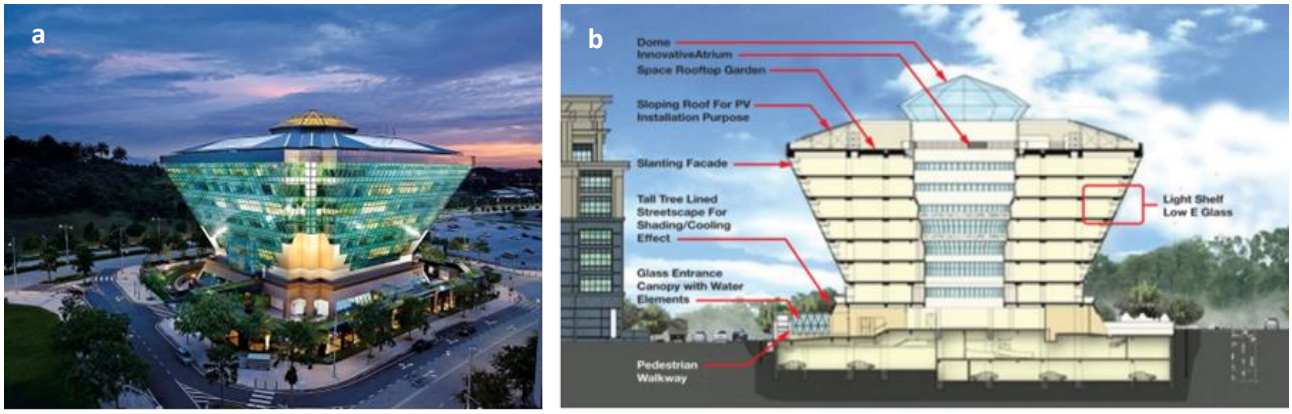

Fig. 1. (a) Diamond building at Putrajaya and (b)building structure of the Diamond building [18]

In 2004, the first building with an energy efficient design that was built by the Malaysian government is the LEO building [19], which is occupied by the Ministry of Energy, Green Technology and Water (KETTHA) [20]. In 2006, the LEO building won the ASEAN Energy Award under the efficient building category. The building is purposely invented to meet the standard of MS 1525: Code of Practice for Energy Efficiency and Renewable Energy in a non-domestic building. However, this building does not meet the standard for the theme of energy savings [21]. The energy consumption of LEO building significantly increased by at least 33% after the temperature for cooling inside the building is decreased from 24°C to 20°C [6].

After LEO, the first green building in Malaysia is the Green Energy Office (GEO) building, and it becomes the country's first Zero Energy Office (ZEO) building [22]. This building was invented with the aims to encourage the building sector to construct more energy efficient and green buildings in the future [15]. On top of that, after 13 years of operation, the GEO building was announced as co-winner in the "Zero Energy Building" category by the 2020 ASEAN Energy Award. The BEI for GEO building is reported as 64 kWh/m^2/year (without Solar PV) and 35 kWh/m^2/year (with Solar PV), and interestingly utilized only 15% of the energy consumption of a typical office building [23].

Another energy efficient building built by the government is the Malaysia Energy Commission Sustainable Building, also known as the Diamond Building. It was located at Putrajaya and built as the

third Government Energy Efficient building with improvised design after the LEO and the GEO buildings. The building design, similar to a diamond shape (cutting edge), utilizes advanced structures for energy efficiency and environmental sustainability [24]. The typical (conventional) BEI of an office building in Malaysia is 210 kWh/m^2 per year. In contrast, the Diamond building is designed with BEI of 85 kWh/m^2 per year, and the average BEI recorded for this building is 65 kWh/m^2 per year [25]. The energy consumption of the Diamond building is approximately 65% [18] from conventional buildings.

Mohamad *et al.*, [26] investigated the energy efficiency opportunities towards green building in one of the government office buildings in Malaysia. They found that improving the physical properties of building components and changing the air conditioner control setting are significant in energy savings for a better green environment. In the book by Tang and Chin [27], due to the Malaysian climate zone passive design would be fits the best for building design in the country. Briefly, passive design can be described as a structure that uses natural sources of energy such as sun and wind integrated with building design to achieve low energy demand for space heating and cooling in the building [27]. However, in a study by Qahtan *et al.*, [28] who investigated the thermal comfort and occupant's satisfaction at energy-efficient buildings in Malaysia, they concluded that indoor thermal comfort is not comprehensively improving because of the air movement. They suggested the use of mechanical ventilation to help improve the air movement in the building. This view is supported by Malik and Ismail [29], who claims that the passive design in tropical climate still needs active systems (mechanical and electrical) to obtain adequate air movement. To sum up these two statements, when designing an energy-efficient building, it is very important to consider the occupant's response to the internal thermal comfort of the energy-efficient building, especially in tropical climates such as Malaysia.

5. Building Retrofitting

Besides executing the building design enhancement and programs, building retrofitting is one of Malaysia initiatives to turn conventional buildings into energy-efficient buildings. Retrofitting involves upgrading building infrastructure [30] to reduce the operational energy [31], reduce operating costs [32] and generate renewable energy and improve environmental performance [33]. Kuala Lumpur Performance Art Centre (KLPac) is one of the Malaysian buildings that implemented retrofitting through renovations of their existing railway warehouse to turn it into a green building. By reusing some of its original structures like brick walls and large doors, the KL Pac project managed to significantly save construction time (29 months earlier) and construction cost (MYR 14 million) compared to a new built green building Shah Alam Royal Theater which has the same functions and capacity [34].

In order to start the retrofit of the building, a thorough audit needs to be conducted to get a complete picture of the costs and opportunities to reduce energy consumption. This will be time consuming as there is a need for prior evaluation before proceeding with the retrofitting process, thus contributing to the reasons on why retrofitting is not an option to improve energy efficiency in building compared to other approaches. Then by taking easy steps, the existing buildings are demolished or abandoned and built or buy the new building rather than retrofitting. Lack of guidelines and concerns from local authorities on retrofitting contributing to community hesitation to initiate an action to retrofit their building. Previously, the Penang State Mosque was retrofitted with an air conditioning system and it was found that energy consumption was still high because the airconds operated continuously for 6.5 hours on a daily basis during both prayer and non-prayer times thus lead to energy waste [35]. To make retrofitting a desirable option, Malaysia needs to start

by providing comprehensive descriptions of the code of practice for retrofitting existing buildings. Then, the community consists of the building owners and tenant/occupant should be made to aware the benefits of retrofit and how it contributes to reducing greenhouse gas emission and energy consumption, and improving energy efficiency.

6. Discussion

In 43 years (1979-2022), Malaysia has implemented various types of policies and programs specifically on energy efficiency. The policies are keep getting updated or renewed from time to time and some of the programs are still being implemented until now, including the NEM and SAVE programs, indicating that the programs have been proven successful in achieving the mission to increase energy efficiency while reducing energy consumption. Unfortunately, citizens are not alert to these programs and some programs are only done at university/school. Hence, all programs should be promoted in all media such as tv, radio, and online promotion like FB, IG, Twitter etc. Another way is to encourage all sectors including private schools, colleges & universities, construction companies, developer etc. to join the programs. Not only the implementation of policies and programs but Malaysia also strives from the aspect of building design and architecture. Several buildings have been built such as LEO, GEO etc.) and retrofitted (KL Pac) in line with the characteristics of green buildings and improving energy efficiency. Besides that, the application of retrofit should be promoted across the Malaysian construction and conservation industries. In line with building developments, retrofitting may be equipped with current information and communications technology (ICT) facilities such as using Internet of Thing (IoT) technology. For instance, retrofitting that featuring smart buildings

Other than the strategies above, the adaptation of initiatives from other countries should be considered by Malaysian government. Although it has never been implemented, it is not wrong for Malaysia to try implement this program because it turns out that this program benefits the country in terms of building energy consumption management. For example, 'Building Energy Efficiency Labelling Program' which has been run by Singapore since 2005 [36]. This program is a joint venture between the Energy Sustainability Unit (ESU) of the National University of Singapore (NUS) and the National Environment Agency [37]. The main objective of the program is to give recognition to the best energy efficient buildings and in turn motivate the building owners. Professionals such as architects and engineers are also encouraged to prioritize the design, development and management aspects of buildings in building current energy efficiency. Among the building criteria that qualifies them to be labelled in this program is that the building must exhibit energy performance among the top 25% in the country as well as be able to maintain a healthy and productive indoor environment. This program is seen to be able to increase awareness among professionals in line with the measures and policies carried out in Malaysia. With a program like this, it can provide an opportunity for employees to continue to improve their work performance and further broaden the view on the importance of energy efficiency. Another approach should be considered to promote energy more widely is using the energy service companies (ESCos). Through ESCos the energy users, companies, industries, and commercial sectors will be guided and helped in improving the efficiency of equipment and analyzing the energy performance and the credit risk [38]. ESCo was successfully implemented in many European Union (EU) countries and few developed countries including the USA, Canada, and Japan [39-40]. However, more research is needed to ascertain the effectiveness of all future implementations because through attentive study the benefits of each strategy can be validated and adapted to current strategies.

7. Conclusion

An overview of energy consumption and energy efficiency in most aspects of Malaysian buildings has been discussed. The literature on Malaysian policies, strategies, and initiatives to increase energy efficiency have been elaborated. This strategy includes the government policies and programs that collaborate with Malaysian local company such as TNB (Tenaga Nasional Berhad) and government agency, SEDA. Despite these policies and strategies may not fully achieve the energy goals, to some extent they affect the energy sector in the country. Therefore, to ensure that energy policies remain relevant and strategies remain effective, the government should constantly review and revise those policies and strategies with appropriate amendments. However, there are several initiatives to improve energy efficiency implemented in Malaysian buildings have been successfully implemented and achieved with excellence such as NEP, NEEAP and SAVE which has been continued till now. The effectiveness of these programs makes Malaysia can be a model country in managing indoor energy systems for tropical climates. Even though some of the strategies need high investment and have many difficulties to execute yet, they might give optimize results on energy consumption and energy efficiency of the buildings in Malaysia. Not only targeting government office buildings, other office buildings in Malaysia should take prudent measures for energy management in buildings. Improvements still need to be made to reduce energy consumption further by introducing energy saving policies or options.

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