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Strategy for Energy-Efficient Office Building of Public University in Malaysia: Case Study

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Abstract: Malaysia's public university campuses should be a good example of pioneering efforts to achieve good energy efficiency in government-owned office buildings. While there is concern about achieving energy efficiency in office buildings, there are still many energy efficiency problems that cause an increase in operating expenses every year. Based on a preliminary energy audit of two main office buildings at two separate public university campuses in Malaysia, this study investigated possible strategies. During the audit process, there was a range of different approaches that were introduced and proposed, which include no-cost, low-cost, and high-cost energy measures. However, in addressing energy efficiency issues, there are three practical energy-saving measures to be considered, not only in the university's main buildings but also in other government office buildings. Such energy-saving measures involve the lighting system, air-conditioning system, and building envelope. The measures chosen as a strategy described in this paper have been researched recently, or are currently on-going studies. All of these strategies have been and are being implemented in these two campuses, and are therefore examples of practical solutions that can be applied according to budget planning and annual budget allocations. The findings and strategies of this study are expected to be a form of guidance to address issues related to energy management in office buildings. The end of this paper provides some recommendations in future and similar studies that may be conducted for all office buildings within these two campuses containing different building designs and features.

Keywords: Strategy, energy management, building energy index, energy efficiency, energy audit

1. Introduction

Energy management plays an important role in our day-to-day life, with particular focus on controlling and reducing the energy consumption of buildings. Optimising a building's energy efficiency rating is a more cost-effective measure, especially for the tropical climate, and Malaysia naturally has an abundance of sunshine and solar radiation that is fairly consistent throughout the year. During the building's operational phase, energy is mostly consumed over the building's lifetime compared with other construction development phases. According to Bano and Sehgal (2020), office buildings typically use energy inefficiently due to the lack of energy efficiency measures and this can result in a substantial increase in recurring expenditure due to high levels of energy consumption.

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Energy is typically used in buildings for heating and cooling, as well as lighting and to power appliances or equipment such as computers, telephones, faxes, and copiers. Therefore, the goal of energy management is to manage energy use so that it would consume the least amount of energy for buildings.

Many energy-saving initiatives applied to the office buildings would cost significant amounts of money. It is very important to choose the right energy-efficient measure at a reasonable cost, which will substantially reduce recurring energy consumption in buildings (Tahir, Nasrun, & Rajemi, 2015). Energy management activity can be implemented with the right strategy and approaches without spending huge amounts of money to achieve a good result (Jamaludin, Mohd Nawi, Bahaudin, Mohtar, & Tahir, 2019). Therefore, energy management is a way of overcoming barriers to achieving optimum energy efficiency. According to Danish, Senjyu, Ibrahimi, Ahmadi, and Howlader (2019), energy efficiency and savings become the focal point of well-managed energy consumption and supply.

2. Energy Management

Energy management is a systematic approach to optimise energy efficiency in a building that can reduce the energy consumption of buildings while at the same time meet users' energy needs and maintaining their level of comfort. According to Gul and Patidar (2015), the energy-efficient building can be achieved within the long term by improving the building design as well as conserving energy during the operational stage. Energy management in the building sector is seen as an approach to make a building's operation more efficient and avoid waste of electricity (Mohd Nawi, Tahir, & Yusoff, 2019).

Due to high demand, the use of the latest technology is also occasionally linked with the introduction of new regulations. The growing demand for energy use in buildings has caused concerns about the growing use of energy to the point that stern action has been taken by introducing building rules concerning energy conservation and technology in many countries. Energy efficiency has been introduced in the building sector through building regulations because it is considered a key element in energy conservation (Kolokotsa, Saridakis, Dalamagkidis, Dolianitis, & Kaliakatsos, 2010; Oh, Hasanuzzaman, Selvaraj, Teo, & Chua, 2018). Energy efficiency technology has been projected to have the potential to reduce carbon emissions by 60% or more and thus conserving conventional energy in the process (Enshen, Zixuan, & Xiaofei, 2005; Fayaz & Kari, 2009).

3. Case Study: Building Profile Area

Two main office buildings were chosen for the purpose of this study at a university located in the north (Building N) and south of peninsular Malaysia (Building S). The selection criterion for this building is that both buildings function as an office or administrative building, and are fully operational throughout the year.

Building N is a six-story building that houses several main offices as the administration office. From Sunday to Thursday, the building operates from 7.30 am to 5.30 pm daily except on weekends and public holidays.

Table 1 - Building N floor area

Building	Floor	Gross Floor Area (m^2)	Total Operational Hours (approximately)
Building N	6 floors	8,983	10 hours

Table 1 above shows that, Building N is a multi-story building with a gross floor area of 8,983m^2. The gross floor area is the overall floor area of all floors in the building, inside the building measured to the exterior wall surfaces, and mostly expressed in square feet or meters. Gross floor area would include stairwells and elevators, but would not include areas such as basements and open space or parking spaces.

Meanwhile, Building S is a five-story building located in the south of peninsular Malaysia, at a public university. The building operates daily from Sunday to Thursday from 7.30 am to 5.30 pm except on weekends and public holidays. The total gross floor area of the building from within the building measured to the outside surfaces of the exterior walls is 16,000 m^2, which was designed to be used as the main administration office house for several main offices, meeting rooms, as well as lecture halls. Since the main office building also houses the university's top management department, it also contains a library with discussion rooms and an auditorium. The building has a very large, cylindrical design and has an empty space in the middle. The building also has large windows on the outside and in the cylinder to allow natural light to penetrate into the building.

The building specifications with the gross floor area are shown in Table 2 below. Similar to Building N, the Building S gross floor area refers to the total floor area of all floors in the building, within the building measured to the exterior wall surfaces and often measured in square feet or meters. For this building, the gross floor area takes into account all stairwells and elevators, but does not include areas such as basements and open space or uncovered car parks.

Table 2 - Building S floor area

Building	Floor	Gross Floor Area (m^2)	Total Operational Hours (approximately)
Building S	5 floors	16,000	10 hours

3.1 Strategy of Energy Efficiency in Buildings

Energy-efficient buildings can be defined as buildings designed to significantly reduce the energy requirement for heating and cooling, regardless of the energy and equipment chosen for heating or cooling the building. An energy-efficient building reduces maintenance and utility costs, while in many cases, improves durability, increases comfort, and creates a healthy and safe indoor environment.

On the other hand, a strategy is related to the idea of making important top management decisions, with specific guidance on achieving goals or missions within the organisation. The energy efficiency strategy in office buildings consists of the planning and significant action taken by management to achieve a standard energy efficiency level. Indirectly, strategies for energy efficiency within office buildings serve as a framework providing energy measures, guidance, and action to be taken, as well as continuous monitoring.

In this case study, various factors were considered in determining the appropriate approach to enhancing energy efficiency in both buildings. Appropriate strategies are therefore crucial in ensuring that implementation of the energy management programme does not burden university management, as it also involves huge government allocations.

There is, in addition, a huge demand for buildings with energy efficiency features at this time, arising from an awareness of local weather conditions, cost-consumption, and environmental impact issues. The rise in demand for energy designs in buildings will continue in the near future due to population growth, long-term use of buildings, and increased demand for improved levels of building comfort (Li et al., 2010; Kamaruzzaman & Zulkifli, 2014). This is because most of the current types of buildings are still being built with conventional designs, thus contributing to inefficient energy consumption and adversely affecting the total energy performance during the building's operational phase (Noranai & Kammalluden, 2012, Garde, Ottenwelter, & Bornarel, 2012, Moghadam, Baharum, & Ulang, 2014; Tahir, Nawi, & Baharum, 2015).

According to Holmes and Hacker (2007, in Georgiadou et al., 2013), conventional building design processes can adversely affect thermal performance of the building envelopes. It can also adversely influence the maintenance and operation of buildings, such as rising utilities and cost of electricity. Thus strategy for optimising a building's energy efficiency is more cost-effective in reducing carbon emissions than using renewable energy. Energy efficiency for the Malaysian climate in office buildings has to be addressed holistically by addressing every opportunity and strategy available.

The following elements can be used to optimise the energy efficiency in a building; lighting system, air-conditioning system, and building envelopes.

3.1.1 Lighting

The buildings' electrical system is distributed to the use of lighting, plug loads, and others, while an artificial lighting system is used to illuminate interior office spaces and exterior areas such as corridors and building façades. There are basically two parameters used to evaluate the efficiency of lighting, namely the density of lighting power and the luminance level. It is very important to have an efficient lighting system because most buildings that are closed and use air conditioning require sufficient light to perform daily activities such as reading and writing. According to Bano and Sehgal (2018), lighting and cooling are essential energy consumption components, responsible for the largest proportion of energy usage in office buildings. The lighting system in both buildings for this case study offers numerous opportunities for cost-efficient energy savings. The technique consists of revising the current lighting scheme. Building operating costs can be reduced with the improvement of the lighting systems. As stated by Kamaruzzaman and Zulkifli (2014) reducing energy consumption of the lighting would reduce the cooling load. Some important criteria for the selection of lighting systems are to reduce energy waste or inefficiencies, taking into account their lifespan, their specific functions, and the key areas to be used in the office building.

There are several opportunities for energy conservation that can be identified, for example, by using a large number of motion sensors in strategic locations or areas to turn on the lights and turn the normal lighting system into more energy-saving lamps, while at the same time delivering output that is comparable to the predefined standard. Some effective energy management techniques such as daylight harvesting, occupancy-based controls, time scheduling, task tuning, personal controls, and response to demand (Dikel, Newsham, Xue, & Valdés, 2018), are not new to today's technology. This all depends, however, on the availability of technology, the building's suitability, and also the annual budget for the operation of an office building. Energy-efficient lighting can also be achieved without incurring high costs by converting the ordinary type of lamp to a more efficient type of light. Improvements in lighting are an excellent investment in most office buildings as lighting accounts for a significant part of the energy bill.

Types of Energy-Efficient Lamps

Fluorescent lamps use 25-35% of the energy used by incandescent lamps to provide a similar amount of light and could last about 10 times longer. Compact Fluorescent Lamps (CFLs), however, use about 80% less energy and fit most installations designed for incandescent bulbs. CFLs are the most cost-efficient and effective in areas requiring long-term illumination. CFLs come in a variety of styles and shapes intended for specific purposes.

Fig. 1 - Compact fluorescent lamps (CFLs)

Light-emitting Diodes (LEDs) have a lifespan many times longer than equivalent incandescent lamps and are significantly more efficient than most fluorescent lamps. It is one of the fast-developing lighting technologies. LEDs come to full brightness immediately, without any delay in heating up. LED bulbs last longer with better light quality compared to other types of lighting. However, light output gradually decreases over the life of the LED.

Fig. 2 - Light-emitting diode (LED) tube lamps

The recommended lighting requirements based on Malaysian Standard MS1525:2014 are shown in Table 3 below. This is a suggestion for lighting power density and lighting requirements for a variety of applications. This information is very useful in designing energy-efficient lighting systems for new buildings and existing ones.

Table 3 - Recommended lighting requirements

Description	Luminance (Lux)	Lighting Power Intensity (W/ m^2)	Example
Public Area	100	5	Corridor
			Entrance hall
			Lobby
			Lift
			Waiting room
			Interior stairs
			Toilet
	150	6	Restroom
	200	8	Cafeteria/ canteen
Work Area	300-400	14	Reading/ writing
			Drawing

3.1.2 Air-Conditioning System

Air conditioning is necessary to maintain thermal comfort in indoor environments, becoming a necessity in office buildings, particularly for hot and humid climates, such as in Malaysia in particular. Chua, Chou, Yang, and Yan (2013) stated that the energy consumed by heating, ventilation, and air-conditioning (HVAC) could exceed 50% of an office building's total energy consumption. Consequently, in this case study, by enhancing the efficiency of HVAC systems in the two buildings, efficient energy performance can have major impact on the buildings' overall energy consumption. This statement is in line with Noh, Yun, and Kim (2011) who explained that the efficient operation of the air-conditioning system can make a significant contribution to the overall energy savings. According to Li, Zhigang, and Zhou (2013), the strategy for optimising the operation of air conditioning system is to ensure that the standard output is achieving indoor comfort while reducing the energy consumption of air conditioning systems by applying measures.

Maintenance Activities

The key function of an air conditioning system is to maintain the level of indoor air quality required for the comfort of occupants in the building. However, it is difficult to determine the feeling of comfort that depends on several factors, including air velocity in the occupied zone. In this case study, the internal temperature for the two buildings was usually approximately 23°C and relative humidity was between 50 and 70%. A good maintenance activity for air conditioning systems is a critical factor in optimising energy usage. According to Tahir, Nasrun, Nawi, and Faizal (2014) the maintenance objective is to reduce the frequency and severity of failures in order to ensure the availability, efficiency, and performance of equipment and buildings at the highest level and acceptability standards. Maintenance issues arise not only in government-owned buildings but also in other commercial office buildings across Malaysia as well. If maintenance issues are first addressed, then issues such as poor system balance and temperature control, long operating hours, and poor operating schedules can be resolved. For cases like maintenance issues, the amount of savings that can be achieved is about 50% of the building's total energy consumption.

However, the easiest solution often taken by building management is to install the split air-conditioning unit in the event of occupants' discomfort inside the office building. This would not only increase the cost of energy consumption but also be a burden on the building's energy consumption. Any proposal to reduce room or workspace temperature by installing separate air-conditioning units should consider the views of energy managers after the energy audit process has been carried out. The development of maintenance programmes for air conditioning systems is, therefore, a key factor in determining to what extent control activities and optimising a building's energy consumption can achieve its targeted objectives.

Control Systems

Ventilation is an important means to control the indoor air quality (IAQ) in buildings. To maintain appropriate levels of IAQ it is important to supply fresh outdoor air and eliminate air pollutants and odours from interior spaces. Originally, the aim of building control systems development was primarily to minimise energy consumption. Thermostats have been used for temperature control feedback. However, changing the setting of thermostats may disrupt the equilibrium of cooling control system in other areas. That will directly increase the building's energy consumption. Building owners for both buildings should, therefore, ensure that thermostats are generally set between 24°c and 26°c to maintain the correct temperature.

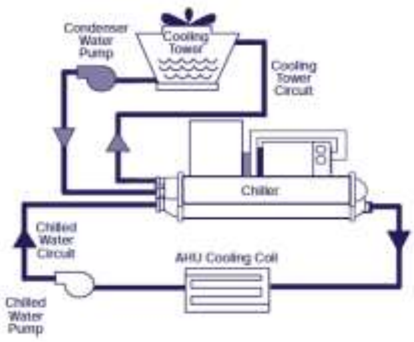

Fig. 3 - Typical water-cooled chiller system (adapted from energy-models)

Noh et al. (2011) proposed an efficient energy management method for buildings with HVAC system installed, where the chiller temperature setting in the HVAC system is controlled to minimise the cost of electricity under real-time pricing tariffs. The efficient and effective operation of the air-conditioning system in the building can make a significant contribution toward energy savings overall. The conventional HVAC systems control the temperature according to a scheduled plan or according to the temperature outside. The chiller uses a significant amount of energy in the HVAC system. Hence, if one were to control the temperature of chilled water efficiently to optimise energy consumption under the current electricity price and retain a level of indoor comfort, then the total operating cost of the HVAC device would be reduced.

3.1.3 Building Envelope

The building envelope is the physical barrier between the exterior and interior environments that encloses a structure meant to protect the interior space from environmental effects. There are certain components that protect interior space from temperature, humidity, and other factors that are related to the environment or external threats. An example of poor performance with the building envelope is poorly insulated walls and windows. According to Sozer (2010), the specific design of building envelope will help achieve the goals of heating and cooling, while increasing energy efficiencies significantly. This statement clearly demonstrates that the proper aspects of the building envelope can ensure the optimum use of energy for the building and thus ensure energy efficiency. However, there is not much that can be done regarding a completed building's envelope, or designed with features that are less energy-efficient. This is because it is certainly expensive to renovate a building that includes the modification of windows, roofs, walls, or flooring. Therefore one would prefer to focus on building orientation aspects that include solar loads imposed on building elements, shading effects of nearby structures, and nearby surface reflection.

Building Orientation

Several previous studies agreed on the importance of building's design stage to overcome any uncertainties in construction variations as well as environmental changes that might influence energy consumption of the building (Tahir et al., 2015). A building's orientation can affect the behaviour of the consumer during office hours. Effective building orientation would thus minimise direct daylight but increase the use of natural lighting to illuminate the occupied area. A good orientation is where a large window area would face either north or south. Based on this fact, a large area of windows at Building N is facing east and west and will receive direct sunlight every day, thus increasing the heat absorbed into the building. Such large window areas facing the east-west direction is recommended to be shaded from the sun rays.

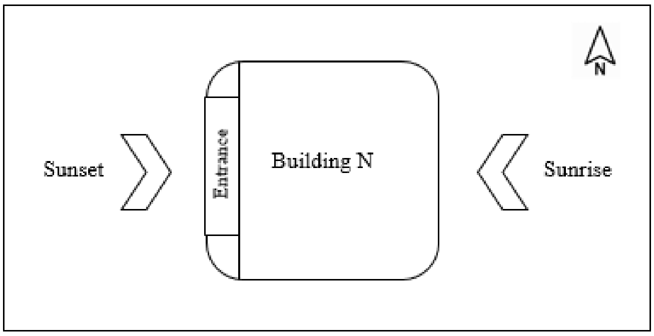

Fig. 4 - Illustrated image from top view for the Building N showing the sunrise in the east and sunset in the west

Fig. 4 shows Building N when the sun rises from the east and sun sets in the west. Based on the illustrated image from the top view, the building's main entrance faces west, and the building's rear receives more morning sunlight. From the building's main entrance, on the top floor, there are windows facing the afternoon sun. During the observation, many windows were open and did not use blinds to prevent glare from the harvested daylight, especially at some point in the day when the critical source of glare is direct sunlight. Likewise, the building's back faces east where the morning sun rises on lots of windows that do not use blinds to block excessive morning sunlight. It is necessary to install more effective sun-shading and to use double glazing windows to prevent more heat from entering the interior of the building. A good landscape can help lower the surrounding temperature, particularly around the building. This will help reduce the heat the building absorbs, that would thereby raise the air conditioning load inside the building. A rooftop landscape, for example, can reduce a lot of heat radiation effects on a building.

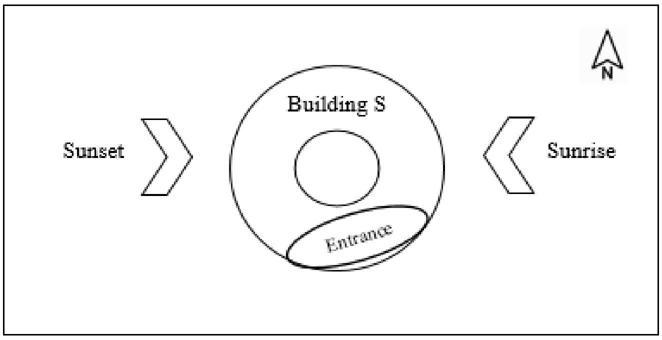

Fig. 5 - Illustrated image from top view for Building S showing the sunrise in the east and sunset in the west

Building S has a very large, cylindrical design and has an empty space in the middle. Illustrated top view image for Building S shows how the sun rises in the east and sets in the west (Fig. 5). The building also has a wide exterior and cylinder windows to allow natural light to penetrate into the building. On the window side, there is no light shield, and consists only of a glazed glass mirror. The building can also maximise the use of natural lighting to light up the occupied area and use less daytime energy. Solar heat gain through windows, however, can account for a significant portion of the air conditioning system load. Internal walls, floors and furniture absorb the solar radiation that passes through the windows and then becomes a burden on the air-conditioning system.

Energy Saving Measures for Building Envelope

There are some very effective methods to avoid the penetration of solar radiation into the building but not all methods are compatible with all types of buildings, including installation and maintenance costs. Among the methods, this paper has identified the use of external shading devices from both of these case studies. External shading systems can minimise direct solar gain through windows for low-rise office buildings (less than 10 floors) such as Building N and Building S, and can minimize solar heat gain by up to 65% (see Fig. 6). Such approaches are generally very economical when it comes to the expense of installing external shading and maintenance for a building like this and not all window positions require external shading devices as the orientation of the building is often considered during the installation process.

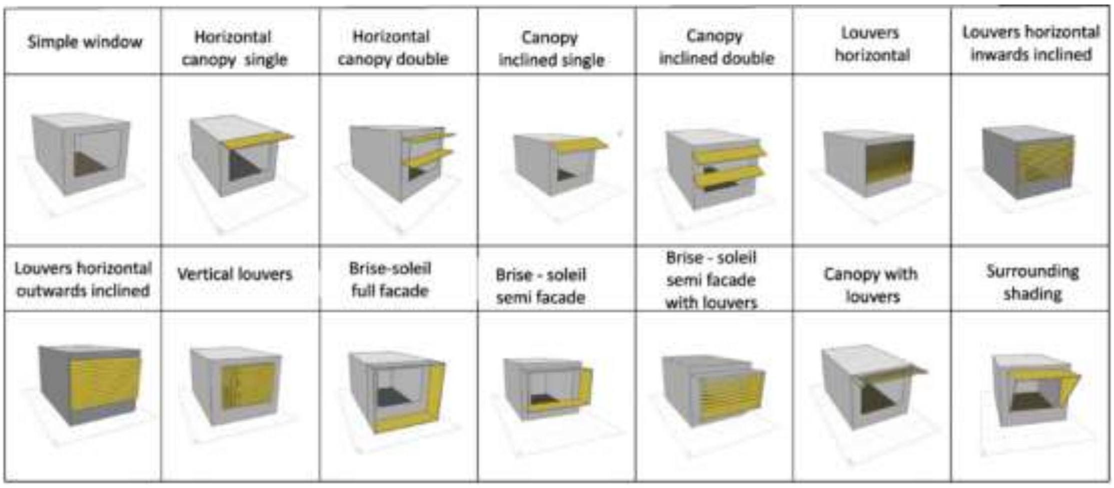

Fig. 6 - Types of shading devices (adapted from Mandalaki, Zervas, Tsoutsos, & Vazakas, 2012)

Building colour also plays an important role, as dark-coloured materials can absorb heat from the sun throughout the year, particularly for office buildings situated in hot and humid climates. White painted office building roofs are cooler than dark roofs and do not lose heat faster. Building N and Building S both have white roofs and experience less heat-absorbing heat. To put it in perspective, it is possible to use such a medium-height office building to create a mini garden on the roof with shrubs and other green plants to minimise heat gain in buildings. A mini-landscape like this will help cool the building's roof and further reduce the load of top floor air conditioning.

4. Conclusion

This paper focused on a case study on office buildings, in order to reduce energy usage in low-rise office buildings. Three of our suggested approaches or strategies concentrated on the lighting system, air-conditioning system, and building envelope based on a preliminary energy audit of two main office buildings at two separate Malaysian public university campuses. Several other approaches were suggested and implemented but in this paper, only three practical energy-saving steps were explored further and are suitable for use in other government-owned office buildings. Such approaches are also very useful as a guide to address the issue of high energy usage across Malaysia's public university campuses, and may also serve as a potential pilot project. In general, it can be concluded that the proposed strategies can have a significant effect on building energy consumption. These strategies must also be based on recommendations that are appropriate, following all guidelines from relevant parties such as the Malaysian Energy Commission. Some of the other recommendations from the study above are:

- Top management involvement in the decision-making process with an energy manager's guidance to ensure that the goals of this strategy are achieved.
- Allocate more time and ample funds to procure more energy efficiency experts, architects, electrical and mechanical engineers, building contractors, designers, and others who may be useful in further discussion and exchanging of ideas.
- It is recommended that consideration be given to technical aspects of technology and operations management so that the strategies become more comprehensive, integrated, and systematic.
- Other factors, including environmental factors (solar radiation, wind, and rain) need to be studied.
- From this study, energy management is not limited to strategies implemented by categories as described in the section on lighting system, air conditioning system and building envelope, and can be in accordance with energy audit results, cost details and features, as well as building features.
- Future studies can also determine the percentage of energy savings from the proposed strategies.

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References

Bano, F., & Sehgal, V. (2018). Evaluation of energy-efficient design strategies: Comparison of the thermal performance of energy-efficient office buildings in composite climate, India. *Solar Energy*, *176*(October), 506–519. https://doi.org/10.1016/j.solener.2018.10.057

Bano, F., & Sehgal, V. (2020). A Comparative Study : Energy Performance Analysis of Conventional Office Buildings at Lucknow. *Journal of Design and Built Environment*, *20*(April), 24–34

Chua, K. J., Chou, S. K., Yang, W. M., & Yan, J. (2013). Achieving better energy-efficient air conditioning - A review of technologies and strategies. *Applied Energy*, *104*, 87–104. https://doi.org/10.1016/j.apenergy.2012.10.037

Danish, M. S. S., Senjyu, T., Ibrahimi, A. M., Ahmadi, M., & Howlader, A. M. (2019). A managed framework for energy-efficient building. *Journal of Building Engineering*, *21*(June 2018), 120–128. https://doi.org/10.1016/j.jobe.2018.10.013

Dikel, E. E., Newsham, G. R., Xue, H., & Valdés, J. J. (2018). Potential energy savings from high-resolution sensor controls for LED lighting. *Energy and Buildings*, *158*, 43–53. https://doi.org/10.1016/j.enbuild.2017.09.048

Enshen, L., Zixuan, Z., & Xiaofei, M. (2005). Are the Energy Conservation Rates (RVRs) Approximate in Different Cities for the Same Building with the Same Outer-Wall Thermal Insulation Measures? *Building & Environment*, *40*(4), 537–544

Fayaz, R., & Kari, B. M. (2009). Comparison of Energy Conservation Building Codes of Iran, Turkey, Germany, China, ISO 9164 and EN 832. *Applied Energy*, *86*(10), 1949–1955

Garde, F., Ottenwelter, E., & Bornarel, A. (2012). *Integrated Building Design in Tropical Climates : Lessons Learned from the ENERPOS Net Zero Energy Building*. 81–90

Georgiadou, M. C., Hacking, T., & Guthrie, P. (2013). Future-proofed energy design for dwellings: Case studies from England and application to the Code for Sustainable Homes. *Building Services Engineering Research and Technology*, *34*(1), 9–22. https://doi.org/10.1177/0143624412463016

Gul, M. S., & Patidar, S. (2015). Understanding the energy consumption and occupancy of a multi-purpose academic building. *Energy and Buildings*, *87*, 155–165. https://doi.org/10.1016/j.enbuild.2014.11.027

Jamaludin, R., Mohd Nawi, M. N., Bahaudin, A. Y., Mohtar, S., & Tahir, M. Z. (2019). Energy Efficiency of Chancellery Building at Universiti Utara. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *58*(2), 144–152.
Kamaruzzaman, S. N., & Zulkifli, N. (2014). Measures for Building Lighting Performance in Malaysian Historical Buildings : A Systematic Review. *Journal of Surveying, Construction and Property*, *5*(1), 1–15

Kolokotsa, D., Saridakis, G., Dalamagkidis, K., Dolianitis, S., & Kaliakatsos, I. (2010). Development of an intelligent indoor environment and energy management system for greenhouses. *Energy Conversion and Management*, *51*(1), 155–168. https://doi.org/10.1016/j.enconman.2009.09.007

Li, G., Zhigang, H., & Zhou, H. B. (2013). The Study on How to Optimize Energy Saving Technology on Central Air-Conditioning for Existing Buildings. *Journal of Clean Energy Technologies*, *1*(4), 339–341 https://doi.org/10.7763/JOCET.2013.V1.77

Li, X., Bowers, C. P., & Schnier, T. (2010). Classification of Energy Consumption in Buildings With Outlier Detection. *IEEE Transactions on Industrial Electronics*, *57*(11), 3639–3644. https://doi.org/10.1109/TIE.2009.2027926

Mandalaki, M., Zervas, K., Tsoutsos, T., & Vazakas, A. (2012). Assessment of fixed shading devices with integrated PV for efficient energy use. *Solar Energy*, *86*(9), 2561–2575. https://doi.org/10.1016/j.solener.2012.05.026

Moghadam, M. H. N., Baharum, F., & Ulang, N. (2014). Influence of Energy Efficient Elements on Energy Saving in Residential Buildings : Case Study of Three Apartments in Penang. *MATEC Web of Conferences*, *9*, 1–6. EDP Sciences

Mohd Nawi, M. N., Tahir, M. Z., & Yusoff, M. N. (2019). Barriers, Challenges and Opportunities for Energy Management Program: A Case Study of Universiti Utara Malaysia. *Journal of Advance Research in Fluid Mechanics and Thermal Sciences*, *60*(2), 1–12

Noh, S., Yun, J., & Kim, K. (2011). An Efficient Building Air Conditioning System Control Under Real-Time Pricing. *The International Conference on Advanced Power System Automation and Protection*, 1283–1286. Beijing: Institute of Electrical and Electronics Engineers (IEEE)

Noranai, Z., & Kammalluden, M. N. (2012). Study of Building Energy Index in Universiti Tun Hussein Onn Malaysia. *Academic Journal of Science*, *1*(2), 429–433. Retrieved from http://universitypublications.net/ajs/0102/html/TRN168.xml

Oh, T. H., Hasanuzzaman, M., Selvaraj, J., Teo, S. C., & Chua, S. C. (2018). Energy policy and alternative energy in Malaysia: Issues and challenges for sustainable growth – An update. *Renewable and Sustainable Energy Reviews*, *81*(June), 3021–3031. https://doi.org/10.1016/j.rser.2017.06.112

Sozer, H. (2010). Improving energy efficiency through the design of the building envelope. *Building and Environment*, *45*(12), 2581–2593. https://doi.org/10.1016/j.buildenv.2010.05.004

Tahir, M. Z., Nasrun, M. N., & Rajemi, M. F. (2015). Building Energy Index : A Case Study of Three Government Office Buildings in Malaysia. *Advanced Science Letters*, *21*, 1799–1802

Tahir, M. Z., Nasrun, M., Nawi, M., & Faizal, M. (2014). Energy Management Study : A Proposed Case of Government Building. *AIP Conference Proceedings*, *1660*(May)

Tahir, M. Z., Nawi, M. N. M., & Baharum, F. (2015). Implementation of Energy Management in Designing Stage of Building. *Advances in Environmental Biology*, *9*(5), 157–159