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Full Length Research Paper

Potentials for sustainable improvement in building energy efficiency: Case studies in tropical zone

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In the past decades, the rapid development of building energy efficiency technologies in the world has gradually deepened people's recognition on this concept in Malaysia, a fast developing economy in the tropical zone. The rapid growth of energy use has raised concerns over problems in supply world wide. This has caused the exhaustion of energy resources and severe environmental impacts such as depletion of ozone layer, global warming, and climate change. Efficient use of energy plays an essential role in minimizing energy usage and carbon dioxide emissions. Having in mind the aim to quantify the current building energy efficiency status in selected buildings and to seek for opportunities to obtain continuing improvement in building energy performance, two case studies consisting of site visits, documentation reviews, questionnaire surveys, and interviews were conducted and the results revealed remarkable insufficiencies in energy efficiency in the studied buildings. Various aspects in improving energy efficiency and renewable energy applications in tropical buildings have been recommended based on the research findings.

Key words: Building energy efficiency, continuing improvement, case study, building energy performance.

INTRODUCTION

The essential purpose of buildings is to provide a protected environment in which to live, work, or accommodate assets. In general, energy cost is one of the highest operating cost components of office buildings, hotels, hospitals and shopping complexes (Jim, 2006; Hassan, 2006). There is very little breakthrough in possible approaches for building energy efficiency studies through out the world (Radhi, 2008; Tang, 2006). Scientific research and technology development are essential for providing the foundation to change current energy production and usage patterns and to reduce vulnerability to interruptions and price volatility (Kevin, 2001). While some progresses have been made over the last 25 years, pace will not meet demand before a critical imbalance develops between the availability of affordable energy and the world's need. Both current science and technology (S&T) and cutting-edge ideas should be pursued to advance new solutions to this problem (Lombard et al., 2008).

In one of the Massachusetts Institute of Technology (MIT) energy research council report, Robert and Ernest (2006) claimed that researchers must makes efforts to achieve the need for new global supplies of affordable, sustainable energy to power the world. The need for workable energy options is perhaps the greatest single challenge facing the world in the 21st century. The acuteness of the challenge at this point in time is resulted from the "perfect storm" of supply and demand, security, and environmental concerns, namely: 1) a projected doubling of energy use and tripling of electricity demand within a half century, calling for a substantial increase in fossil fuel supplies or dramatic transformation of the fossil fuel-based energy infrastructure; 2) geological and geopolitical realities concerning the availability of oil and, to some extent, natural gas specifically the concentration

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of resources and political instability in the Middle East; and 3) greenhouse gas emissions from fossil fuel combustion are increasingly at the center of decisions about how the global energy system should evolves – one that carries on in the “business as usual” overwhelming dependence on fossil fuels or one that introduces technologies and policies that greatly improve efficiency, dramatically expand the use of less carbon-intensive or “carbon free” energy, and implementation of capture and sequestration of large scale carbon dioxide. Lighting energy being used in most buildings can routinely be cut down from 30 to 50% through a combination of improved technology, automatic controls, and better lighting design (EPA, 1999). Nevertheless, more than half of existing commercial building floor area still uses old-style, less-efficient systems. Efficient lighting designs are only being used in a small minority of spaces, and control systems that maximize the use of daylight are even less common. The trendy and exposed designs of the 1980s and 1990s in multi-level buildings have abandoned many so-called “good practices” of the 1960s and 1970s, such as double facade in the exterior of buildings to prevent direct sun heat. However, mechanical cooling is heavily applied in today’s modern buildings (Azni et al., 2006). Mega designs and large scale governmental construction projects have led to a surge in energy demand in many buildings in Malaysia. Boxy and extended designs have led to many confined interior spaces without any windows. Such designs should consider giving way to slimmer designs and construction to allow more application of natural ventilation techniques around the structure (Azni et al., 2006). With the aim to investigate the current energy efficiency status in building lighting and to seek for opportunities to obtain further continual improvement in energy performance, a case study was conducted in DENSO-Malaysia and results revealed a great potential for further enhancement in its building energy efficiency.

Energy efficiency in buildings

In the 1980s, innovations in technology have led to major improvements in the energy efficiency, performance, and cost-effectiveness of commercial lighting systems such as the electronic ballasts development, fluorescent lamps advancement, occupancy sensors, and enhanced lenses and reflectors. However, such systems achieved low adoption rates not only in the construction of new facilities but also in the renovation of existing buildings (Dolin, 1997). Anomalies in consumer behavior that induce inefficiencies in markets for energy-using equipment have drawn much focus and caused emphasis in both research and policy (Nair et al., 2010; Sanstad and Howarth, 1994). These anomalies in consumer behavior can somehow be related with the results by Howarth et al. (2000) which indicated that factors related to corporate culture, structure, and management practices play essential roles in mediating decisions to invest in energy-efficient technologies. Artificial lighting is one of the major sources of electrical energy costs in office buildings, both directly through lighting energy consumption and indirectly by production of significant heat gain, which increases cooling loads. Electric lighting represents up to 30% of building electricity consumption in commercial and office buildings (Crisp et al., 1988; Lam and Chan,1995).

As claimed by Howarth et al. (2000), it is well documented that private-sector fails to systematically exploit opportunities to minimize costs through enhanced energy efficiency. In a research conducted on school buildings, it revealed the advantageous to achieve cost saving by bringing down energy consumption. In order to achieve this, the first step is to design an action plan which involves specific actions and the targeted projects should be consulted frequently and reviewed annually. The second step is to motivate staff and pupils to adopt good housekeeping (Filippin, 2000). As a consequence, opportunities for continuing improvement in the energy performance in Malaysia are substantial and are to be highlighted in this circumstance. Behavioral changes in life styles and energy consumption patterns in people are also required to face the challenge in reducing emission of green-house gases at local and global levels, and the use of more energy efficient production, processing and distribution technologies (UICN, 1995).

The building energy consumption in lighting is a major contributor to carbon emissions and the heat gains produced from such lighting have an important influence upon heating and cooling loads as reported by BRE (1997). With the aim of identifying how technological interventions might reduce emissions by 50% by the year 2030, a program is investigating the carbon emissions of UK buildings as reported by Peacock et al. (2005). This program was based on the estimations made with respect to technological and building improvements that, although not necessarily readily available in 2005, should be obtainable within the next twenty one years until 2030. Several building categories such as domestic, office and retail are being investigated. Several different types of building are defined that are indicative of that category within each category. For the buildings investigated in this program, electrical lighting accounts for a substantial proportion of carbon emissions as reported by Peacock et al. (2005). In this regard, the opportunities for continuing improvement in energy efficiency building needs to be further explored. Apart from this, it is believed that the improvement of energy efficiency in building can serve as an alternative to minimize the emissions of carbon dioxide and to care for the environment. Lenssen and Roodman (1995) estimated that in the urban building systems, almost one half of the global CO_2 emissions can be attributed each year to the combustion of fossil fuels. Setting aside the construction process, in 1992, operations in buildings were responsible for one third of the total energy consumption, and 26% of this amount was due to fuels burning (Filippin and Beascochea, 2007). By bringing down the combustion of fossil fuels through improvement of energy efficiency in building, it is of great potential to reduce this one half of global CO_2 emissions.

Notwithstanding that the lack of costly monitoring causes managers to overlook investments in energy efficiency that are truly advantageous (Ross, 1986; Porte and van-der-Linde, 1995), rational decision making by both managers and employees leads to an institutional framework in which transaction costs impede the adoption of cost-effective technologies that would generate significant environmental benefits. It can be inferred that decisions from both managers and employees are of utmost important in adoption of energy efficiency in buildings. Buildings indentified in the study region might have a poor performance in energy and economic terms (Verbruggen, 2003).

Building energy efficiency in Malaysia and lingering problems

Energy efficiency is the use of less energy to produce the same amount of services or useful output (Karkanias et al., 2010; Chung et al., 2006). The rapid growth of energy use has already raised concerns over problems of supply world wide. This has caused the exhaustion of energy resources and severe environmental impacts such as depletion of ozone layer, global warming, climate change, etc. In developed countries, especially in the country of Malaysia, the global contributions from residential and commercial buildings towards energy consumption have steadily increased to a figure between 20 and 40% (Saidur, 2009). Nowadays, buildings energy efficiency is a prime objective for energy policy at regional, national, and international levels due to growth in population, increasing pressure for building services to assure the continuing of upward trend in future energy demand (Omar and Mohammed, 2004; Jaber at al., 2003). The current energy and socio-economic systems are clearly unsustainable and undoubtedly will exhaust fossil fuel resources in generating electricity for commercial and domestic uses. This will have a serious impact on the environment because of the life styles of the developed nations and will lead to patterns of consumption increasing energy needs and, consequently, carbon dioxide concentrations in the atmosphere (Lombard et al., 2008; Olanrewaju et al., 2010). Energy efficiency is merely among many qualities valued in a building and some of these, such as large glass surfaces, may even counteract energy efficiency (Nassen and Holmberg, 2005). The rapid growth of demand for energy is expected not only in the developing countries but in developed countries too, as they attempt to reach a higher living standard (Yamtraipat et al., 2006; Radhi, 2008). Efficient use of energy will play an essential role in minimizing energy usage and associated emissions released to the atmosphere (Farhanieh and Sattari, 2006).

One of the most cost-effective measures in reducing emission of carbon dioxide as the main causes of global warming is through the improvement of energy efficiency in buildings (Lombard et al., 2008; Chow, 2001; Uchiyama, 2002). To comply with measures to save energy and reduce environmental pollution, Malaysian government has already built low-energy office (LEO) buildings whose energy intensity is 114kWh/m^2, which is only 50% of that in conventional buildings (LEO, 2005). However, this building as one demonstration has very few followers. In encouraging the usage of renewable energy, the Malaysian government has put 5% renewable energy usage in its 9th Malaysian plan to reduce the environmental burden on the atmosphere. In addition, University Science Malaysia Centre for Education and Training in Renewable Energy and Energy Efficiency (CETREE) is actively playing a role to create awareness of energy efficiency and usage of renewable energy among the end users (Saidur, 2009). The ineffective distribution of costs and benefits between actors makes the promotion of energy efficiency in the new construction to be particularly complicated in Malaysia (Azni et al., 2006). On top of that, to the residents energy cost is a small and well-hidden part of the total rent (Ryghaug and Sorensen, 2009). In relation to supply strategies, there may be a number of reasons why energy efficiency often falls short. One of the reasons is the problem of imperfect information which is typically more pronounced in the market of energy efficiency. The service of energy efficiency may consist of a series of small changes with unclear estimates of costs and benefits. Unlike energy supply issues which are driven by major actors, energy efficiency also lacks influential advocates (Azni et al., 2006). Furthermore, households or landlords who made the investments in energy efficiency generally require much shorter payback times than investments in supply extension made by major specialized energy companies (Olanrewaju et al., 2010; Hassan, 2006).

RESEARCH METHODS AND PROCEDURES

Two case studies consisting of site visits, documentation reviews, questionnaire surveys, and interviews as a combined approach were conducted within Malaysia to investigate the current building energy efficiency status and to seek for opportunities to obtain further continual improvement in energy performance. The first case study was conducted in a double storey building named LESTARI, which is located in the Bandar Baru Bangi campus of Universiti Kebangsaan Malaysia (UKM). The building was built in December 1999 with gross floor area of 2374.92 m2. The main function of the building is for office use and research activities. Studies have been conducted in its building envelop, orientation, windows and blinds, infiltration, and thermal comfort. Two questionnaire surveys and one interview survey were employed in this case study.

The second case study was conducted in DENSO-Malaysia Sdn

Table 1. Working questions and activities.

Working questions	Methods for analysis	Empirical data used
How to reduce the lighting energy consumption?	Site visit interviewing the energy manager	Electricity bills
How to optimize the usage of day-lighting?	Identifying the targeted area	Breakdown of energy consumption
How to reduce the usage of air-conditioning?	Clarifying the planned and future activities	Plant layout of the offices

Table 2. Observations on building envelop of LESTARI.

S/N	Observations on building envelop
1	There are no improper alignment and operation of windows and doors which allow excessive infiltration
2	There are no worn, broken or missing parts of infiltration areas
3	Some doors and windows which separating conditioned and non-conditioned areas are left open
4	There is no excessive expanses of glass exist on the exterior walls
5	There is no insulation between conditioned and unconditioned spaces
6	There is no inadequate or damaged roof, but have broken ceilings, as shown in Figure 1
7	All windows are provided with blinds

Bhd, which is a Japanese industry specialist in high quality and technologically advanced automotive components, located in Bandar Baru Bangi, Selangor Darul Ehsan, Malaysia. The reason for choosing DENSO-Malaysia Sdn Bhd is because in comparison to many local factories, it has started to recognize the importance of conducting its business consistently with environmental conservation and energy efficiency. DENSO has established its forte in the production of engine-related, electronics and body-related products since 1949, when it was first founded as Nippondenso. The DENSO global network is headquartered in Japan and extends to over 198 companies across 31 countries. Studies were conducted into its current energy status and energy efficiency in office lighting systems. Economic analysis and recommendations for better energy performance are also provided. Documentation reviews and a questionnaire survey were employed in this case study. The reason for choosing these two cases is because the first case was totally planned, constructed, and financed by the Malaysian local institutes while the second case was planned and financed by a renowned foreign firm operating in Malaysia, so that comparisons could be made between the two types of buildings. More detailed information of research procedures are summarized and tabulated in Table 1.

RESEARCH FINDINGS AND INTERPRETATION

Case study results in LESTARI, UKM

LESTARI is a double storey building with gross floor area of 2374.92 m^2, which is located in the Bandar Baru Bangi campus of Universiti Kebangsaan Malaysia (UKM). The building was built in December 1999 and its main function is for office use and research activities. The daily occupancy rate of the building is averagely 65% and daily operating hours range from 10 to 12. The observations on its building envelope are listed in Table 2.

Building orientation and windows

Building orientation due south, or slightly east of south performs best to reduce east and west exposures as demonstrated in Figure 2. The ideal exterior sun control strategy is illustrated in Figure 3. However, LESTARI building is surrounded with windows and most of those windows are facing east and west, which leads to plenty of heat gain from direct sunshine as shown in Figure 4. Although LESTARI building does not have the best orientation, direct sunshine is controlled by vertical blinds behind each window. Hence, the heat gain from solar radiation at the east-facing and west-facing windows could be reduced.

Infiltration

Infiltration is the uncontrolled inward air leakage through cracks and interstices in a building element and around windows and doors of a building, caused by the effect of wind pressure and the differences in the output/input air density. 30% of doors in LESTARI are between conditioned areas and non-conditioned areas (including outdoor) and have poor air infiltration. Warm air carries heat and the moisture from non-conditioned areas into conditioned areas, which cause serious energy losses.

Figure 1. The broken ceilings in LESTARI.

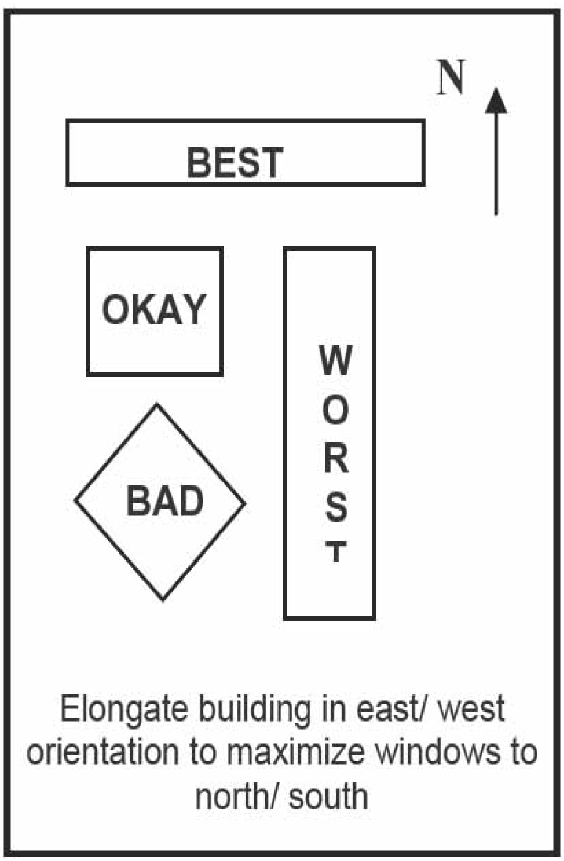

Figure 2. Building and window orientations.

As shown in Figure 5, there is an air gap at the door of the Air Handling Unit (AHU) room. AHU is a device used as part of the heating, ventilating and air-conditioning. An AHU is usually a box which contains a blower, a heating and/or cooling elements, filters racks or chambers, sound attenuators and dampers. An AHU is usually connected to ductwork that distributed the conditioned air through the build and returns it to the AHU. The air gap allows fresh air to enter into the AHU room, which affects the cooling efficiency. Thus more energy is required to run AHU at the desired level. Air leakage should never be considered as acceptable natural ventilation because it cannot be controlled or filtered, and will not provide adequate or evenly-distributed ventilation. This is generally the opposite of the requirements for ventilation within buildings. Reduction of air infiltration may account up to 20% of energy saving potential in heating dominated climates. Not only are windows and doors usually weak points which need to be well designed, also walls, ceilings and joints between building elements have this same deficiency. The air infiltration through cracks in walls, windows and doors are the major problems at the conventional building. There are no cracks on walls, windows or doors which allow excessive infiltration at LESTARI building while windows, which should be used in separating conditioned areas and outdoor areas, are left open during most of the office hours as shown in Figure 6.

Existing thermal comfort

A small questionnaire survey was conducted in the morning, afternoon, and evening sessions, respectively, where respondents were requested to report on thermal comforts according to the location (zones) of their working place. The divided zones in LESTARI building

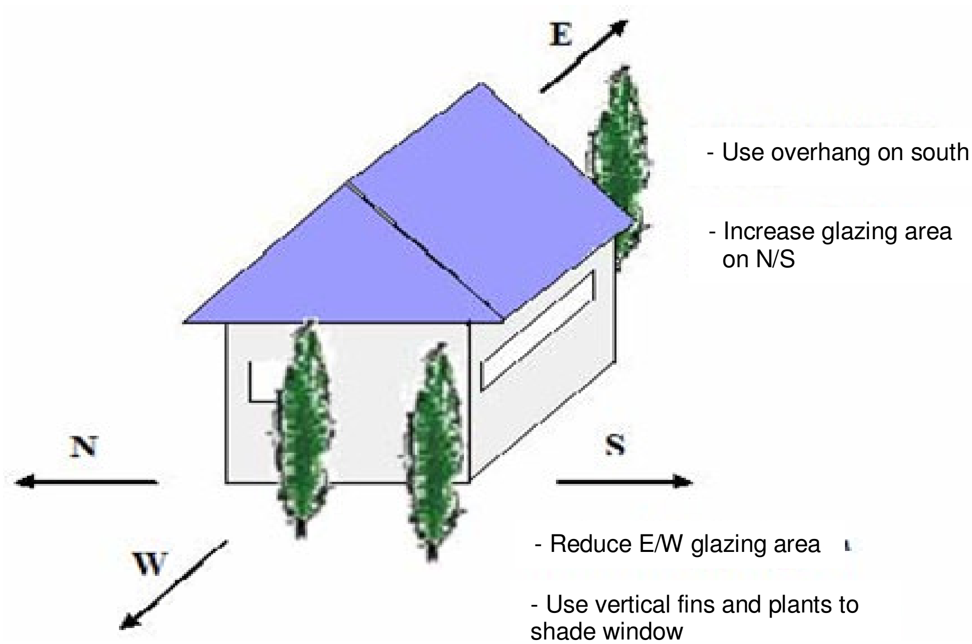

Figure 3. Building exterior sun control.

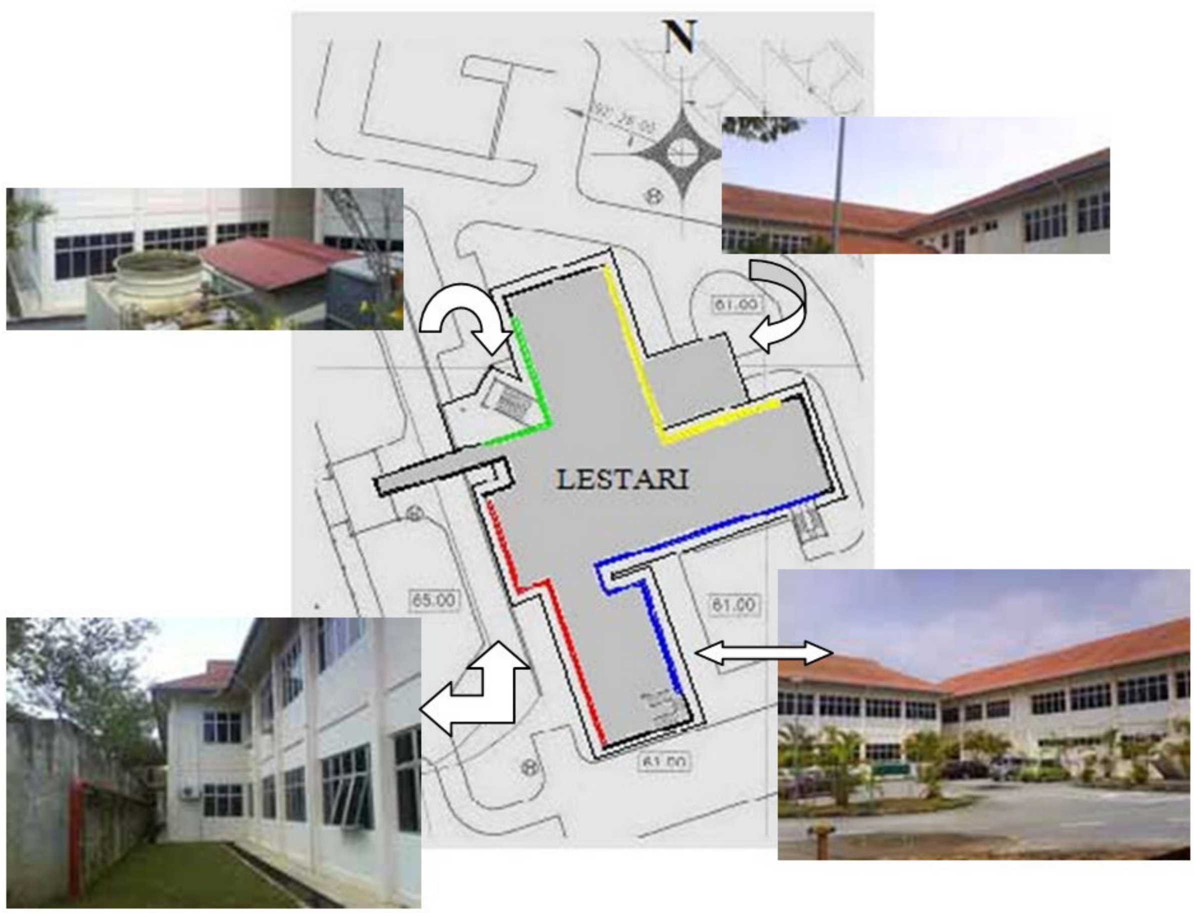

Figure 4. LESTARI building and window orientations.

Figure 5. Air gap under the door of AHU room in LESTARI (Viewed from inside of the room).

Figure 6. Windows are left open during office hours in LESTARI.

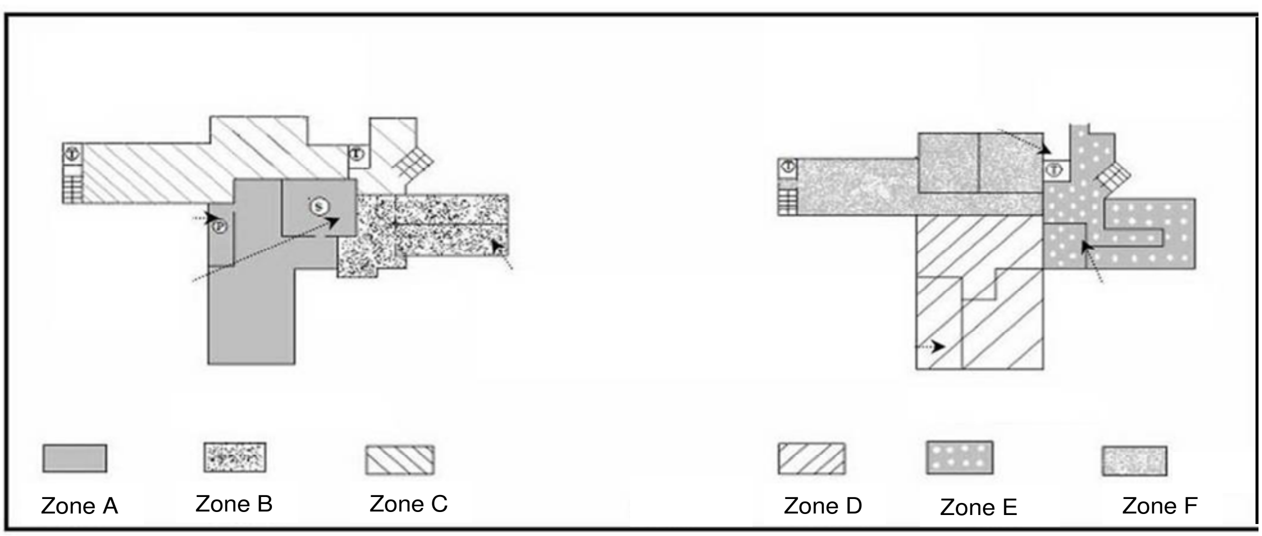

Figure 7. Divided zones of areas in LESTARI building.

are shown in Figure 7. The occupancy distribution of the survey respondents in LESTARI building is shown in Table 3. The comfort levels were evaluated in four levels, namely: too cold, cold, comfortable, and hot. The results for morning, afternoon, and evening sessions are illustrated in Tables 4, 5 and 6, respectively. Results show

Table 3. Occupancy distribution of the survey respondents in LESTARI.

Zone	Number of respondents
A	8
B	11
C	14
D	0
E	0
F	3
Unknown*	5
Total	**41**

Table 4. Thermal comfort of occupants in LESTARI in the morning.

Zone	Morning			
	Too cold (%)	Cold (%)	Comfortable (%)	Hot (%)
A	50	38	13	0
B	82	0	18	0
C	69	15	15	0
D	N.A	N.A	N.A	N.A
E	N.A	N.A	N.A	N.A
F	0	33	33	33
Unknown	40	40	20	0

Table 5. Thermal comfort of occupants in LESTARI in the afternoon.

Zone	Noon			
	Too cold (%)	Cold (%)	Comfortable (%)	Hot (%)
A	57	14	29	0
B	42	42	17	0
C	31	46	23	0v
D	N.A	N.A	N.A	N.A
E	N.A	N.A	N.A	N.A
F	0	0	100	0
Unknown	40	60	0	0

that during most of the office hours occupants feel too cold in the LESTARI building, which leads to poor thermal comfort and energy waste in air-conditioning. In addition, more than 90% occupants in LESTARI put on jackets, blazers or sweaters during office hours as shown in Figure 8.

Use of blinds

All windows in LESTARI building are installed with blue color vertical blinds. A questionnaire survey was conducted to investigate the use of binds and sunlight in LESTARI. As shown in Figure 9, half of the occupants who are sitting near to the windows often use blind with close tilt. The reasons for using blinds are divided into three, namely: glare problem, blocking direct sunlight, and privacy purpose. Figure 10 shows LESTARI occupants' responses to the sufficiency in lighting using only daylight. Although 61% of the occupants agreed that day lighting is sufficient during office hours, the problems of glare heat gained from sunlight still prevent them from using it, this causes 78% occupants to use blinds in close tilt.

Table 6. Thermal comfort of occupants in LESTARI in the evening.

Zone	Evening			
	Too cold (%)	Cold (%)	Comfortable (%)	Hot (%)
A	75	0	25	0
B	73	18	9	0
C	46	23	31	0
D	N.A	N.A	N.A	N.A
E	N.A	N.A	N.A	N.A
F	0	33	67	0
Unknown	80	20	0	0

Note: there are no respondent from Zone D & E.

Building Energy Index (BEI)

Building Energy Index (BEI) (kWh/year/m^2) is the total electricity consumption (kWh) per year per unit of occupied area (m^2). With the information of LESTARI building listed below, the BEI of LESTARI was calculated in Equation (1).

Building Type and Category: School/ Public University;
Building Use: Office;
Total Electricity Consumption (kWh/year) = 388752 kWh/year;
Gross Floor Area (m^2) = 1432.72 m^2

$$BEI = 388752 \text{ (kWh/year)} / 1432.72 \text{ (m}^2\text{)} = 271.34 \text{ (kWh/year/m}^2\text{)} \quad (1)$$

In the code of practice on Energy Efficiency and Use of Renewable Energy for Non-residential Buildings (MS1525), it is suggested that the target BEI for office buildings is 136 kWh/year/m^2. The energy performance of LESTARI building is still far from the suggested target and is higher than that of the conventional office building categories at 205 kWh/year/m^2 (Hishamuddin, 2007). Therefore, the energy performance of the LESTARI building is not in an efficient condition.

Figure 8. Occupants in LESTARI building putting on jackets, blazers, or sweaters during office hours.

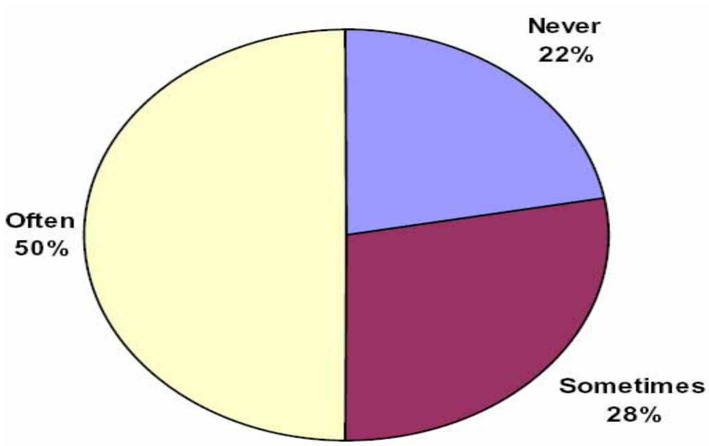

Figure 9. Frequency of using blinds in LESTARI.

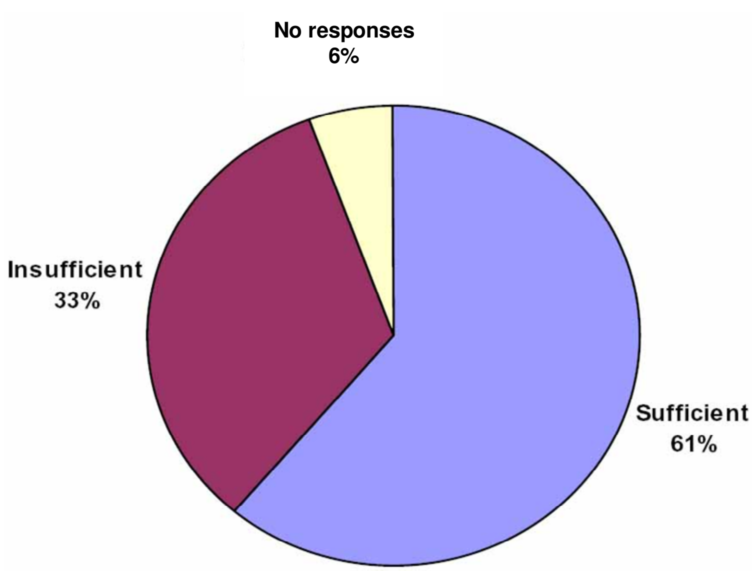

Figure 10. Sufficiency in lighting using only daylight in LESTARI Notes: Data compilation based on 18 respondents with working place near to window.

Potentials improvements for LESTARI building

Window materials

The existing window design of LESTARI building is natural anodized aluminium window completed with frame, transome, mullion, galzing beads, and ironmongery. The casements of the windows consist of top hung and side hung panels. Film coating was not used for the windows in LESTARI. The glass used is 6mm thick single pane of clear sheet glass. As the Malaysian climate is equatorial and the cooling load is a major concern, tinted glass or solar control low-emissivity (low-e) coating might be a good suggestion for window design. Window films are generally a retrofit option, intended to fix a problem with excessive solar heat gain and solar glare from an existing window. As stated in the ASHRAE Fundamentals, the glazing light transmission and solar heat gain coefficient (SHGC) of glazing system with single 6mm thick clear glass are 89 and 81% respectively (Public Work and Government Services Canada 2002). Solar Heat Gain Coefficient (SHGC) is a ratio of total transmitted solar heat to incident solar energy for a glazing. The ratio ranges between 0 and 1 and is an indication of the total heat transfer of the sun's radiation. An older, similar term, the Shading Coefficient (SC), as used in MS1525, is the ratio of the solar heat gain of a glazing to that of a clear single glazing (SC = 1.15 × SHGC). The higher value of SHGC represent the more heat transferred from the sunlight to the indoor. Whereas visible transmittance (VT) is a measure of the fraction of visible light that passes through a glazing.

The ideal window films for LESTARI building are those with high visible transmittance value and low SHGC. If the VT value is greater than the SHGC value, the glass transmits more light than heat. The light-to-Solar-Gain (LSG) ration is the VT value divided by the SHGC value. The higher this ratio, the more spectrally selective the film and the better it is for reducing cooling loads purposes. For the areas where they are moderately well shaded, the VT value while choosing a suitable window film is suggested as about 0.45 - 0.55. Whereas for other areas where they have bright, not shaded exterior scene, lower VT value which ranges from 0.25 to 0.40 can be chosen. Another option is to install replacement insert low-e windows within existing frame and soft or sputtered low e-coatings, which these coatings are sprayed onto glass to achieve a low emissivity. They are referred to as 'soft' because they are susceptible to degradation if exposed to the atmosphere. Provided they are in a sealed glass unit, they will retain their properties. Early soft coats had an emissivity of 0.1 (Public Work and Government Services Canada, 2002). More recently developed coatings achieve emissivity of less than 0.05. Most of these coatings are spectrally selective, in that they have high visible light transmission but low solar transmission. These coatings are best suited to medium-to- large commercial buildings or buildings with high air conditioning loads.

Daylight and shading system

Energy can be saved by dimming or switching off electric lights where there is sufficient day lighting. Furthermore, when the internal cooling load from the lights is reduced, the air-conditioning energy requirements will be reduced as well. These combined savings from reduced lighting and cooling loads have potential of 25 to 40% of total saving of the overall office building energy requirements (Leslie 2002). Shading system is meant to control sunlight entry and glare. There are two types of shading systems, namely interior and exterior shading. Exterior shading devices are more effective than interior shades at controlling solar gains (Public Work and Government Services Canada 2002). Interior shading is effective at minimizing uncomfortable glare from direct beams of light, but is not effective at solar heat gain minimization because it does not prevent the sun's heat from entering the space. Table 7 compares the visible transmittance and the reduction in solar heat gain (SHGC) for Venetian and vertical blinds. There are no exterior shading devices for all the windows in LESTARI except some of which benefit from vegetations as shading elements. In LESTARI, 80% of desks were located more than 2 meters from a window and thus electrical lighting are needed even during the day time while the tilt of the blinds are closed. The functions of blinds are not fully used in LESTARI. As interior shades, all the windows are to be provided with white color fabric vertical blinds. The white color fabric vertical blinds are helpful in reducing glare. The light color and the vertical type perform better in reducing solar heat as compared to other types of blinds.

Case study results in Denso (Malaysia) Sdn. Bhd.

DENSO is a Japanese industry specialist in high quality and technologically advanced automotive components. The DENSO Group has established its forte in the production of engine-related, electronics and body-related products since 1949, when it was first founded as Nippondenso. The DENSO global network is headquartered in Japan and extends to over 198 companies across 31 countries. DENSO (Malaysia) Sdn. Bhd. recognizes the importance of conducting its business and is consistent with environmental conservation and energy efficiency.

Current energy status

The energy breakdown of DENSO is illustrated in Figure 11.

Table 7. Visible transmittance and SHCG for interior shades in LESTARI.

Shading type	Visible transmittance (%)	Reduction in SHGC (%)
Venetian blinds		
Light color	5	33
Dark color	5	29
Vertical blinds (closed)		
Light color	0	60
Dark color	0	18

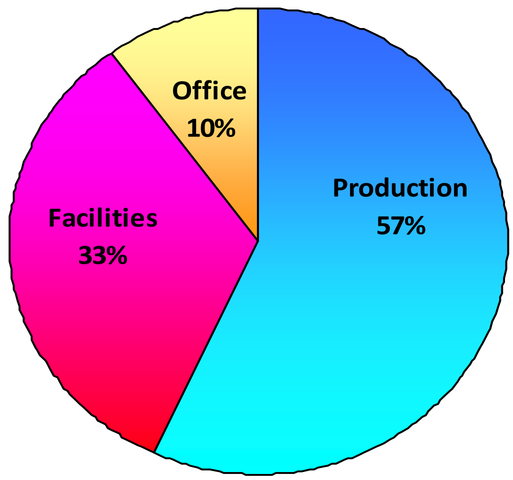

Figure 11. Energy Consumption Breakdown in DENSO.

Table 8. Breakdown of energy consumption in office plants in DENSO.

Breakdown of energy usage	S/N	Office plant	%
Distribution of Energy Consumption by each plant (P101, P102 and P103)	1.	Plant 101 (electronics plant)	51
	2.	Plant 102 (thermal plant)	29
	3.	Plant 103 (thermal plant)	20
Breakdown for individual plant	1.	Plant 101 & 102 (office plants)	44
	2.	Plant 103 (office plants)	46
Breakdown of Energy Consumption for office plants (10%)	1	Air-conditioning	6
	2	Lighting	3
	3	Other	1

It shows that the production plants consume most of the energy followed by facility and office plants. The production plants take 57% of the energy consumption and the facility plants take 33% while office plants take only 10%. Although office plants contribute only 10% of total plant consumption, there is still much room for improvement. Table 8 indicates the energy consumption for each plant in the office buildings where P101 takes 51% and the P102 and P103 take 29 and 20%, respectively. Table 9 portrays the floor area of studied

Table 9. Floor area of studied places in DENSO.

Places	Area (m^2)
P101 main office	2280
Canteen	1400
P102 office	391
P103 office	918
P103 canteen	340

Table 10. Current status of lighting usage in DENSO.

S/N	Location	Quantity (pieces)	Operating hours (per day)	Energy consumption (kWh)		Total consumption (kWh)
				Fluorescent ballast capacity (36W)	Conventional ballast capacity (10W)	
1	Main office (P 101)	492	12	212.55	59.04	271.59
2	First floor office (P 102)	158	12	68.25	18.96	87.21
3	First floor office (P 103)	366	12	158.1	43.92	202.02
4	Canteen	182	12	78.8	21.84	100.64
Total kWh per day						661.46

Table 11. Total percentage of saving with energy saving ballasts in DENSO.

S/N	Location	Quantity (pieces)	Operating hours (per day)	Energy consumption (kWh)		Total consumption (kWh)
				Energy saving T5 ballast capacity (28 W)	Electronics ballast capacity (3W)	
1	Main Office (P 101)	492	12	165.3	17.7	183
2	First floor Office (P 102)	158	12	53.09	5.7	58.79
3	First floor Office (P 103)	366	12	122.97	13.2	136.17
4	Canteen	182	12	61.16	6.54	67.7
Total kWh per day						445.66
Total saving kWh per day:						215.8
Percentage (%) saving						32.6%

places in DENSO.

Current status of lighting system at DENSO office

Table 10 shows the current status of lighting usage in the DENSO office buildings and Table 11 indicates the total percentage of saving with proposed lighting system. As delineated in Table 11, the total saving of energy consumption with the proposed lighting system is 215.8 kWh which is equivalent to 32.6%. Consequently, the replacement of the existing lighting with energy saving lighting and electronics ballast is highly recommended as 32.6% of energy will be saved.

Economic and cost saving analysis

DENSO uses E2 tariff which is RM 0.208 per kWh during day time. The details of saving and return of investment (ROI) are shown in Tables 12 and 13. From the analysis conducted, it was indicated that by implementing the energy saving lighting it will save about 32% of energy and if translated into economic DENSO, it can save cost up to RM 14,005.68 per year. The estimated cost for replacing energy saving lighting is RM 53,910 and the payback period is 3.8 year. From the observation made, it is also found that there is a potential to eliminate some of the lighting in the office due to high illumination at certain area, but further study needs to be carried out to investigate this matter.

DISCUSSION ON RESEARCH FINDINGS

The case studies conducted in LESTARI and DENSO-Malaysia reveal a great potential for further enhancement in their energy performance. The BEI of the LESTARI building is 271 kwh/m^2/year which is even higher than the conventional office building (205 kwh/m^2/year).

Table 12. Annual saving using T5 in office plants in DENSO.

S/N	Location	Total consumption conventional lighting (kWh)	Total consumption energy saving T5 (kWh)	Total saving per day (RM)
1	Main Office (P 101)	271.59	183	18.43
2	First floor Office (P 102)	87.21	58.79	5.91
3	First floor Office (P 103)	202.02	136.17	13.70
4	Canteen	100.64	67.7	6.85
Total Saving per day (RM)				44.89
Total saving per month (RM)				1,167.14
Total saving per Year (RM)				14,005.68

Table 13. Energy ROI in DENSO.

No.	Location	No. of unit	Cost (RM) per unit electronics ballast (RM 30)	Cost (RM) per unit energy saving lamp (RM 15)	Total Cost (RM)
1	Main Office (P 101)	492	14,760	7,380	22,140
2	First floor Office (P 102)	158	4,740	2,370	7,110
3	First floor Office (P 103)	366	10,980	5,490	16,470
4	Canteen	182	5,460	2,730	8,190
Total cost (RM)					53,910
Pay back period					3.8 Year

Most windows are facing east and west, which lead to plenty of heat gain from direct sunshine so that vertical blinds were used to reduce the direct solar radiation. Film coating was not used for the windows in LESTARI. In addition, most of the occupants in this building prefer to close the blinds during office hours which would be a constraint for the utilization of day lighting. There are 30% of doors in LESTARI between conditioned and non-conditioned areas (including outdoor) which have poor air infiltration. Further, windows are kept open during office hours while air-conditioning is on. The thermal comfort is poor in LESTARI that more than 90% occupants put on jackets, blazers or sweaters during office hours. Even though Denso-Malaysia Sdn Bhd is a Japanese specialist in high quality and technologically advanced automotive components, results have revealed a lot space for further enhancement in energy efficiency. Malaysia is one of the British Commonwealth Nations and a fast developing economy in the world, however, in comparison with the study conducted by Peacock et al. (2005) in the UK, the level of energy performance in building lighting is much lower than that in Britain, especially due to the lack of using energy saving electronic ballast. Another reason might be because Malaysia is one of the oil exporting countries so that the energy issues are not as urgent as that in the UK. It is suggested that DENSO looks into the aspects listed in Table 14 to improve energy efficiency and renewable energy applications in buildings. An energy management program is also suggested to be developed.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

Two case studies were conducted in LESTARI and DENSO-Malaysia to investigate the building energy efficiency status in the tropical zone and seek opportunities to obtain continuing improvement in building energy performance. Results have revealed great potentials for further enhancement. Saving can be achieved through improvements in building orientation, film coating,

Table 14. Recommendations for energy efficiency in DENSO.

S/N	Recommendations	Output/Impact	Investment category (Cost)		
			None	Low	High
1	To obtain the detailed breakdown of the electricity bill for the plant and the offices in respect of the electricity tariff especially during the peak and off-peak hours	Leveraging on the usage of electric tariff during the Off-peak and peak hours	√		
2	To fully utilized the day-lighting at the canteen area	Lower down the energy consumption by switching off the Outer and Inner daylight at the canteen area	√		
3	To transfer from the canteen washing the heat extracted plant oven to the for the usage of dishes and other purposes	Transfer heat technology which can lessen the usage of heat and electricity use in the canteen		√	
4	To engage an Energy Audit Consultant and to perform audit to get the detailed breakdown of the energy usage for the whole plant	Able to identify which other plants that can make improvements		√	
5	To engage an Energy executive	Monitoring of any irregularity in energy consumption to reduce further waste of energy		√	
6	To optimize the day lighting at the windows by using special tinted glasses	Tinted windows from Ultra Violet and Infra Red by allowing only the light radiation will reduce the intensity usage of Air-conditioning and also lighting		√	
7	Install lighting sensor in office (for the purpose of lunch time and break)	Reduce human error in implementing energy saving		√	
8	To study the possibility to use rainwater as water storage and for the flushing purposes in toilet	Free use of rain water as an alternative		√	

shading, infiltration, and applications of day lighting. Besides that, replacing conventional electrical lamps with high efficient types of lighting devices using MS1525 guideline may reduce energy consumption in building lighting. Future studies on energy management programs are strongly recommended to optimize building energy performance in the tropical zone.

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