A CASE FOR PASSIVE ARCHITECTURE AS A GAIN IN FACILITIES MANAGEMENT

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Abstract

The objective of this paper is to demonstrate that Passive Architecture gives significant Energy Savings Benefit that is advantage to Facility Management (FM). Passive Architecture is an assertion for energy conservation where building elements are passively designed and strategised for comfortable indoor conditions. Consequently, the building operation becomes less dependent from commercially supplied energy and offers Energy Savings Benefit. This idea was demonstrated using a computer simulation by comparing energy use in a living/dining area of a house with consideration of Passive Architecture (PA Case) and a version that disregards Passive Architecture design strategies (non-PA Case). The features of these cases were based on two actual houses with opposite characters in Bangi, Malaysia. The resultant indoor comfortable conditions in the two cases were compared against the standards. Whenever the PA Case did not need to use artificial lighting or mechanical cooling, it therefore, claimed Energy Savings Benefit. It was found that the living/dining area in the PA Case had effect for substantial monetary value of Energy Savings Benefit for one year, making Passive Architecture a significant cause. Passive Architecture is a fundamental action before using Energy Efficient equipment or applying Renewable Energy system whereby the latter is relatively expensive and the payback period takes a long time to materialise. By understanding the significance of Passive Architecture, FM professionals could further explore the idea in a wider context and be more effective in the building industry.

Keywords: Passive Architecture, Facilities Management and Energy Savings Benefit.

Malaysia's energy demand

A study for the Economic Planning Unit to support policy decisions for the 9th Malaysia Plan predicted a steady rise in energy demand in Malaysia from present to year 2020 (NIRAS, 2005) (Fig. 1).

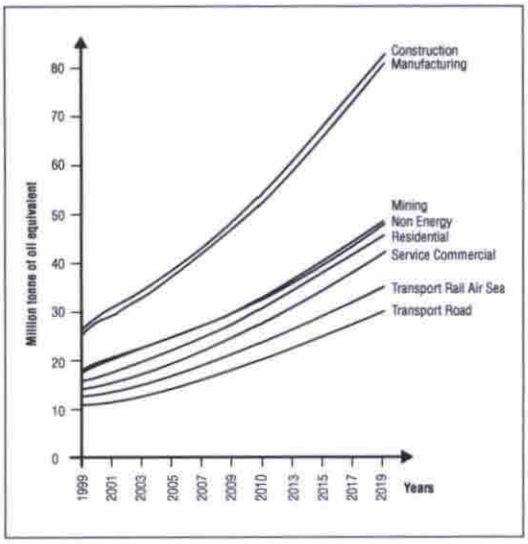


Figure 1:
Proposed final energy demand from 1999 to 2020 (extracted from NIRAS, 2005).

This claim of increased energy demand is supported by a report from the Energy Commission (2008) that showed the electricity sales of the main energy company in Malaysia, Tenaga Nasional Berhad (TNB) had been increasing for the last 5 years (Fig. 2). Parallel to that is the rising fuel subsidies recorded at RM4.8 billion, RM6.6 billion and RM7.6 billion in years 2004, 2005 and 2006, respectively (Ismail, 2007).

There are three major issues resulting from the continual increment in energy demand and subsidies. Firstly, subsidies cannot be sustained by the government for a long time because it is a fiscal burden as well as an opportunity cost (NIRAS, 2007). Subsidies will inevitably reduce or come to an end and the actual cost of energy will have to be passed down to the consumer, perhaps in the form of tariff hike. Secondly, the bulk of energy source

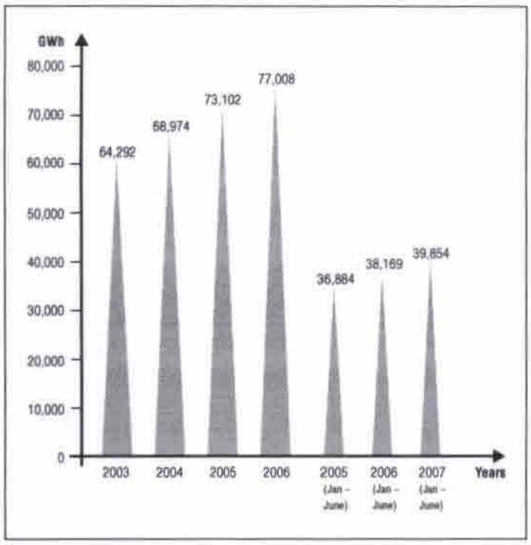


Figure 2:
Total sales of electricity by TNB from 2003 to mid 2007. (Extracted from Energy Commission, 2008)

comes from fossil fuel and it is depleting (Smith, 2005). Thirdly, the main by-product of energy production is carbon dioxide (CO2) which is found to be the main contributor to the global warming phenomena (Szokolay, 2006). Some studies claimed that the excessive increment in CO2 will speed up the process of planet Earth self-destruction (Smith, 2005). In conclusion, the increasing demand in the commercially supplied energy is not good news.

Facilities Management (FM) and energy

A study in the industrialised countries claimed that the building industry emits 50% of the total CO2 in the course of its construction and throughout its lifetime (Smith, 2005). In hot and humid tropical climate, building needs Operational Energy (OE) mainly to cool the living space besides providing artificial lighting so that occupants feel comfortable. FM has a direct connection to this aspect of building via its core competency of Operation and Maintenance (O&M). It has been an ongoing effort in FM to reduce OE in building by applying Renewable Energy (RE) or Energy Efficient (EE) equipment (Ismail, 2007). However, such initiatives have limited takers because the issue from stakeholders' points of view are not adequately addressed. For instance, the payback time for RE is too long and the return on investment is hardly recouped by the building's first owner (Smith, 2005).

Presently, FM has gained gradual recognition of its role in the building industry and it is identified as one of the key organisation that could effect for the reduction in energy consumption (Lim, 2007). Furthermore, FM encompasses multiple disciplines and its circle of influence in the built environment includes various people, such as client, consultant, contractor, occupants, authorities, etc., as well as process and technology (Gilleard, 2007). Nonetheless, to be effective in this quest, FM must demonstrate the economic benefits of low energy building to stakeholders way ahead of the O&M stage, i.e., at the design phase. This paper demonstrates the benefits of Passive Architecture whereby building is sensibly designed to avoid dependency on commercially supplied energy and become an advantage in championing effective FM.

Passive Architecture

Passive Architecture is a climate responsive building that provides comfortable indoor conditions, without relying on mechanical cooling or artificial lighting (Szokolay, 2006). In hot and humid tropics, this means avoiding solar radiation, promoting ventilation from the prevailing wind reducing humidity level and ensuring daylight into the building. The maximum impact can be achieved by strategising the building elements such as orientation, form, opening and sun shading devices to achieve the said goals (Olgyay, 1963; Hyde, 2000). Passive Architecture is not a new idea. Traditional houses in the tropics had exemplified Passive Architecture by means of raised floor, low thermal mass envelope and raised/jacked roof to facilitate ventilation (Fig. 3).

Generous openings like windows, doors and ventilation outlets are deliberately positioned to encourage natural ventilation (Olgyay, 1963; Hyde, 2000). Shallow rooms elongated from east to west and faced north performs better in achieving comfortable indoor conditions (Hyde, 2000). It was also found that natural ventilation is more successful in slender room since prevailing wind in the tropics does not have high velocity (Olgyay, 1963). Traditional

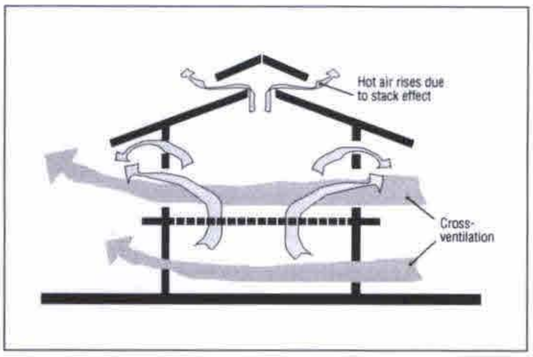


Figure 3:
Cross-section of a traditional house showing the ventilation concept with arrows depicting the flow of air.

house also put emphasis in encouraging daylight as much as possible into its rooms via openings that are well shaded to reduce heat gain. Generally, Passive Architecture is elementary as it asserts Energy Conservation (EC) at the design stage to reduce OE in building (Fig. 4).

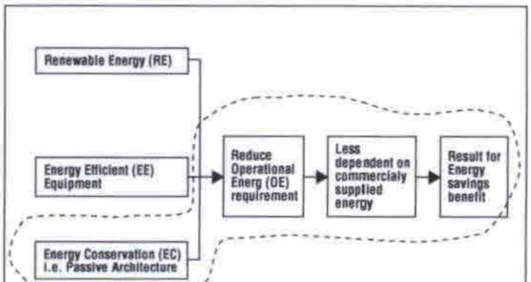


Figure 4: Passive Architecture asserts Energy Conservation that reduces Operational Energy in building.

Thermal comfort and visual comfort

A building can be made independent from mechanical cooling when the occupants feel thermally comfortable. There are two components of variables that influence thermal comfort, namely microclimate and occupant's personal adaptation (Auliciems & Szokolay, 1997). Meanwhile, to be independent from artificial lighting, occupants must sense visual comfort. Good amount of daylight enables occupants to carry out their activity in the house without resorting to artificial lighting (Majoros, 1998).

Comfort variables affect the indoor conditions differently at various times and these factors do not work in isolation. For example, alleviating heat gain using external sun shading devices can affect the amount of daylight entering a room. Therefore, it is important to present the potential of Passive Architecture with reference to the combined effects of both thermal and visual comforts.

Energy Savings Benefit (ESB)

The intended effect of Passive Architecture is the "savings" in the operational energy, termed as Energy Savings Benefit. This could be made tangible by comparing the energy consumption in buildings of similar type. In this study, building is being represented by a detached house. Theoretically, a house that is designed for maximum daylight will need less commercially supplied energy when compared to another that has no consideration for daylighting (Baker & Steemers, 2000). In this instance, the Energy Savings Benefit claimed by the former occurs when it does not need to use artificial lighting (Fig. 5).

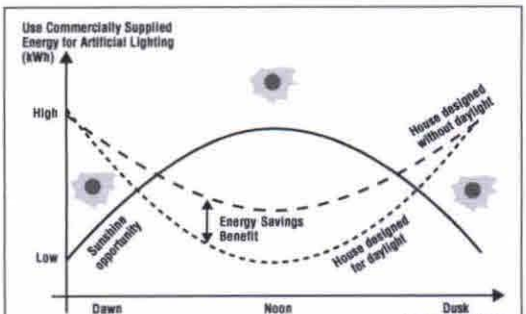


Figure 5: Theoretical use of commercially supplied energy for artificial lighting.

Similarly, a house with good natural ventilation will require less mechanical cooling compared to the one with poor ventilation; hence, claiming Energy Savings Benefit from mechanical cooling. Nonetheless, such comparison is only valid when it is made on a levelled platform, whereby the two houses must be of the same locality and size. In addition, the behaviour of the occupants in both houses has to be the same.

Methodology

A simulation study of two cases was carried out to demonstrate the Energy Savings Benefits from Passive Architecture. The key design features of two detached houses in Bangi, Malaysia of opposite qualities were used as basis of the simulation where the resultant comfortable conditions of the two cases can be compared.

The first case was designed to imitate key design features of a Passive Architecture precedent currently under construction (Fig. 6).

Figure 6: A detached house (under construction) in the Bangi, Malaysia endeavours to achieve Passive Architecture goals via wide openings facing north.

This case is termed as 'PA Case' and has the following design strategies (Fig. 7):

North orientation;

- Slender form elongated east-west;
- Large openings on the north facade; and
- Recessed floor plan on the north and south sides.

Another case is simulated based on the key features of a typical house in the vicinity that lacks of Passive Architecture considerations (Fig. 8). Generally, many houses in Malaysia have little consideration on orientation, form, opening and shading devices. For example, the orientation of the typical house selected does not respond to climate conditions. Like many others, it responds to the main access road. As a result, frequently used spaces such as living/dining

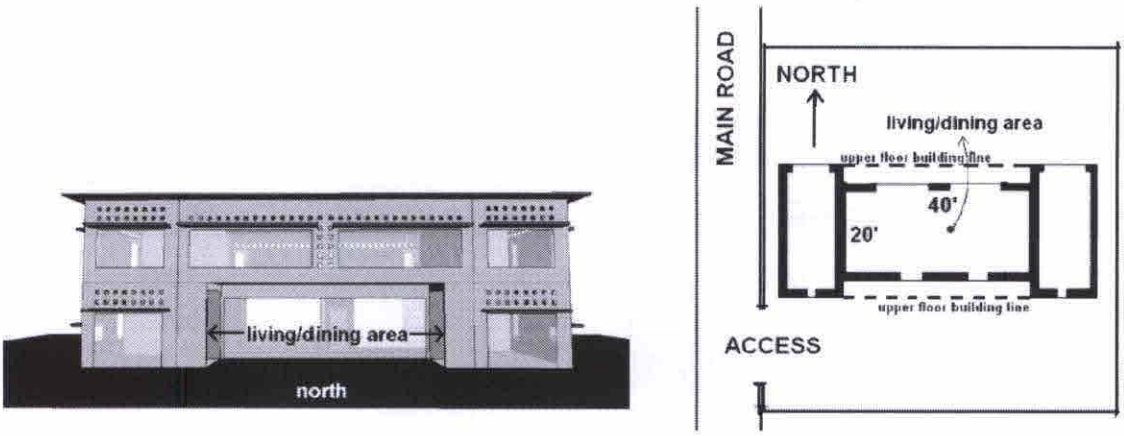


Figure 7: Simulated elevation and site plan of PA Case showing elongated form.

areas faced west and get the most of heat gain. In addition, the form of such house is normally square reflecting the squarish lot area. Consequently, it results for concentric space arrangement with less natural cross ventilation. Furthermore, the openings are placed according to aesthetics rather than to facilitate natural ventilation and shading devices are normally underprovided.

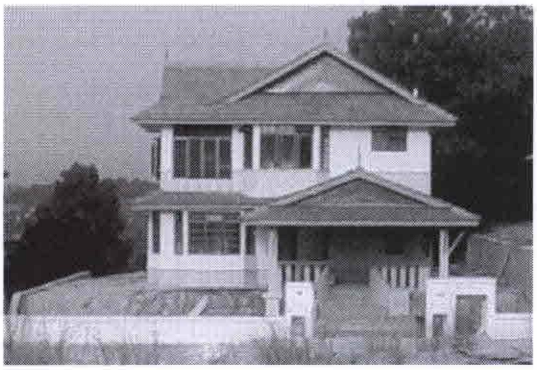


Figure 8: An example of a typical detached house (under construction) in the Bangi, Malaysia that lacks of Passive Architecture design considerations.

Based on the above, a 'non-PA Case' was simulated with the following features (Fig. 9):

- West orientation;
- Square form with concentric rooms arrangement;
- Medium-sized openings on all facades with undersized shading devices; and
- Porch at the front, not for climatic reasons but for vehicle parking.

Both PA and non-PA cases have the same floor area, volume and method of construction but the total cause of orientation, form, openings and sun shading devices, or the lack of it, was treated as one effect for one definite value of indoor comfortable conditions (Table 1). The value of Energy Savings Benefit in the PA Case was determined by comparing it against the energy use in the non-PA Case. For this paper, the study was limited to the living/dining area only.

Scale of measurement

The study assumed that occupants, microclimate, and material were constants. The simulation readings in the two houses were taken on every 15th day of the month for a year. Based on Auliciem's equation, $T_n = 17.6 + 0.31T_m$, where T_n is Thermal Neutrality and T_m is the mean temperature for the locality of the case, i.e., 27.4°C for Klang Valley area; T_n works out as 26.1°C (Sh. Ahmad, 2004). It was assumed that when the building offers comfort zone in the region of 2.5K from T_n (for 90% acceptability), the occupants would not require the aid of mechanical cooling.

The illuminance (lux) readings for visual comfort were compared with recommendation by the International CIBSE (Chartered Institution of Building Services Engineers) Standard; for living/dining area is 300 lux

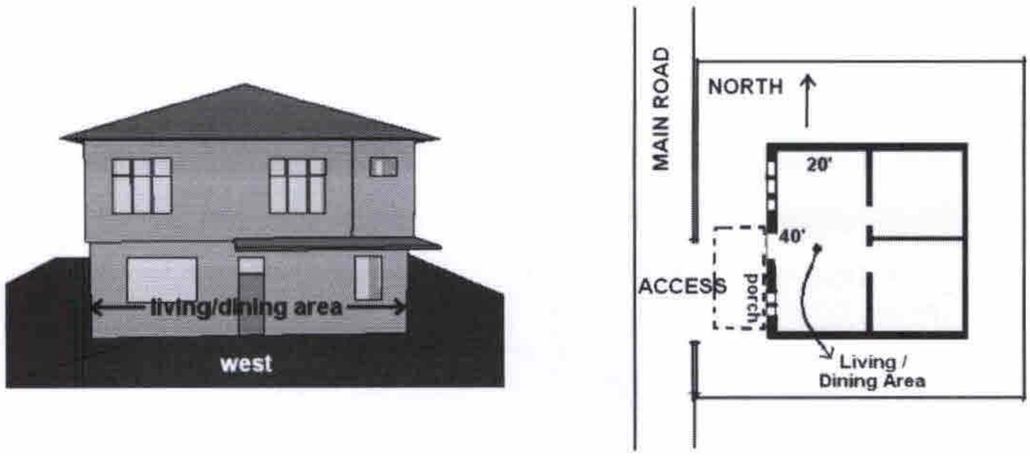


Figure 9: Simulated elevation and site plan of non-PA Case showing square form.

Table 1: Cause and effect of PA and non-PA Cases.

SAMPLE	CAUSE	EFFECT
PA Case incorporation Passive Architecture design strategies  PA Case	Building elements (orientation, form, openings and sun shading devices) were designed to achieve Passive Architecture goals	=> long period of comfort => need less mechanical cooling / artificial lighting => low operational energy => need less commercially supplied energy => claims Energy Savings Benefit
Non-PA Case disregards Passive Architecture design strategies  Non-PA Case	Building elements were merely construction elements	=> short period of comfort => rely on mechanical cooling / artificial lighting => high operation energy => need more commercially supplied energy

(CIBSE, 1994). It was assumed that when the space gave such illuminance reading, it would not require artificial lighting and that personal adaptation would not involve any operational energy (Majoros, 1998).

Results of visual comfort analysis

The illuminance reading measured daylight opportunity under standard overcast sky as defined by the CIE (Commission Internationale d'Eclairage). The duration was approximately 12 hours from 7:00 a.m. to 7:00 p.m. every day, except during winter solstice. The daylight analysis was carried out onto an imaginary working plane of 0.85 metre-high in the living/dining area to reflect the operational level.

Generally, it was found that the illuminance readings in the space were not consistent. For example, on 15th June, area closer to the window had high illuminance reading compared to the centre of the space. In this instance, even when one-third of the space read 300 lux, it was assumed that the occupant would still need artificial lightings in order to compensate for the insufficient luminaire at the other part of the space. When this happened, the area was generalised as having inadequate daylight.

The fluctuation in the luminance reading on the 15th June can be translated into the need for artificial lighting in the living/dining area (Fig. 10).

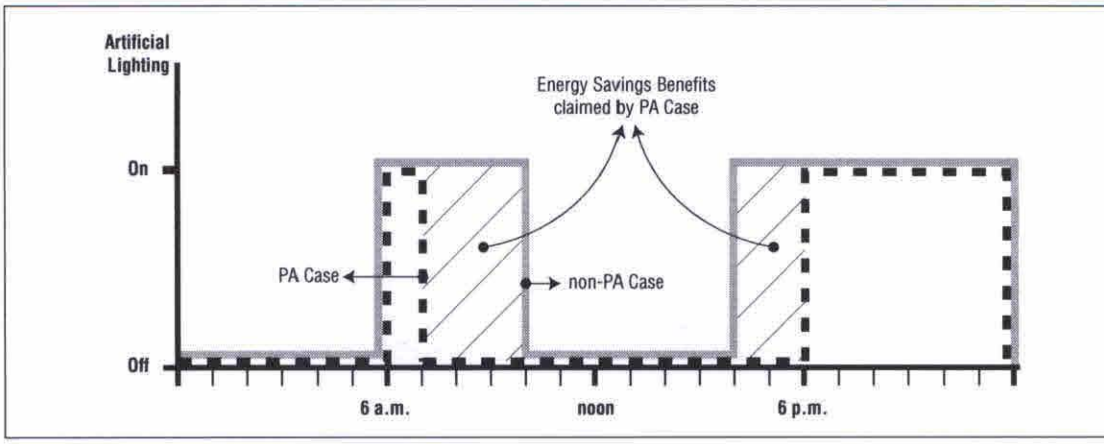
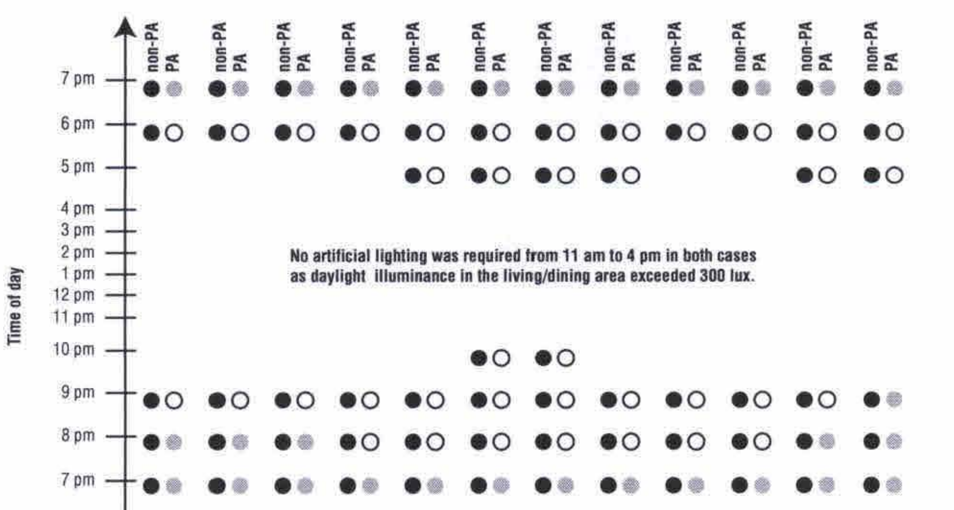


Figure 10: Use of artificial lighting by PA and non-PA cases on 15th June.

On this particular day, both the PA and non-PA Cases required artificial lighting at night time. However, during daytime non-PA Case needed artificial lighting several hours longer in the morning and late afternoon when compared to the PA Case. Assuming that in both cases the living/dining area was unused after midnight till 6 a.m., the Energy Savings Benefit claimed by the PA Case occurred when it did not require artificial lighting for five hours as compared to the non-PA Case.

When simulated for every 15th day of the month, non-PA Case had insufficient daylight and had to rely on

Table 2: Time and hours when the living/dining area of non-PA Case and PA Case had to rely on artificial lightings on every 15th day of the month and the resultant Energy Savings Benefit (ESB) [marked as 'o'].



Month	Jan	Feb	Mac	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days	31	28	31	30	31	30	31	31	30	31	30	31
ESB/day	2	2	2	3	4	5	5	4	3	3	3	2
ESB/month	62	56	62	90	124	150	155	124	90	93	90	62

artificial lighting for at least five hours per day (Table 2). PA Case had inadequate daylight for a maximum of three hours per day but it had maintained to be above the minimum luminance requirement during most part of the day. Assuming readings on every 15th day represented a typical day of the month; PA Case could claim Energy Savings Benefit up to 155 hours per month or 1158 hours per year which averaged at 96.5 hours per month.

Monetary value of Energy Savings Benefit from artificial lighting

The monetary value of the Energy Savings Benefit was derived with reference to the same lighting provision in the living/dining area in both the PA and non-PA cases. It was assumed that the light fittings can be either of the following types:

- Two 36 watt Energy Efficient (EE) 4-foot long fluorescent lights, equally spaced at the living/dining area; or

- Three sets of two 100 watt incandescent light bulbs equally spaced in the area.

Commercially supplied energy was provided by the main electricity company, the National Electricity Board or Tenaga Nasional Berhad (TNB) and the domestic tariff for the first 200kW was 21.80 sen/kWh but increased to 28.90 sen/kWh for the next 800 kWh (TNB, 2008). Based on the above, the monetary value of one-year Energy Savings Benefit from artificial lighting in PA Case was deduced to be (Ringgit Malaysia) RM151.44 if used incandescent lights and RM17.52 if applied EE fluorescent lights (Table 3).

Results of thermal comfort analysis

The reading on 15th June showed that the minimum indoor air temperature in the non-PA Case was 28.9°C and this had exceeded the thermal comfort range of 2.5K from Thermal Neutrality, T_n of 26.1°C. Meanwhile, the indoor air temperature of the PA Case was in the range of thermal comfort in the morning. During post-meridiem the indoor air temperature of PA Case only slightly exceeded the thermal comfort zone and the occupants may or may not require mechanical cooling at this time. However, the study assumed that whenever the thermal reading exceeds comfort zone, occupants would opt for mechanical cooling.

Based on the above and assuming no one uses the living/dining area between midnight and 6:00a.m., the Energy Savings Benefit claimed by the PA Case on 15th June happened when it did not need mechanical cooling for 6 hours compared to the non-PA Case (Fig. 11).

Simulations on every 15th day of the month showed that the non-PA Case would require 18 hours mechanical cooling to bring the room temperature down into the comfort zone. On the other hand, the PA Case appeared to need only 12 hours of mechanical cooling because the space fell into the

Table 3: Calculation of monetary value of Energy Savings Benefit (ESB) from artificial lighting (incandescent, EE fluorescent) claimed by living/dining area in PA Case.

Item	**Calculation Description** Note: RM is Ringgit Malaysia TNB is National Electricity Board	**Three sets of two 100-watt incandescent lights**	**Two EE 36-watt, 4-foot long fluorescent lights**
(A)	Energy required by artificial lighting	0.6 kWh	0.072 kWh
(B)	Average ESB per month = (A) x 96.5 hours / month	57.9 kWh	6.95 kWh
(C)	TNB Domestic Tariff for first 200kW @ 21.80 sen / kWh / month	RM 12.62	RM 1.46
(D)	One-year value of ESB from artificial lighting = (C) x 12 months	RM 151.44	RM 17.52

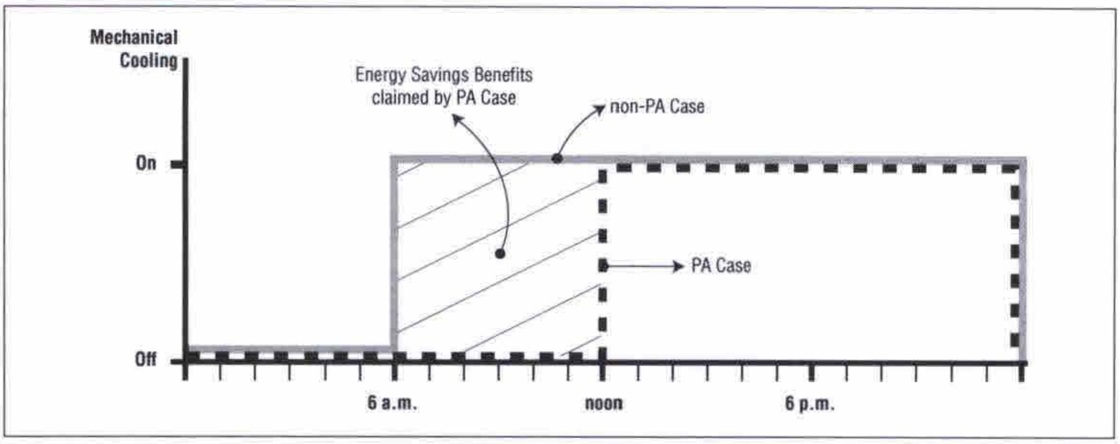
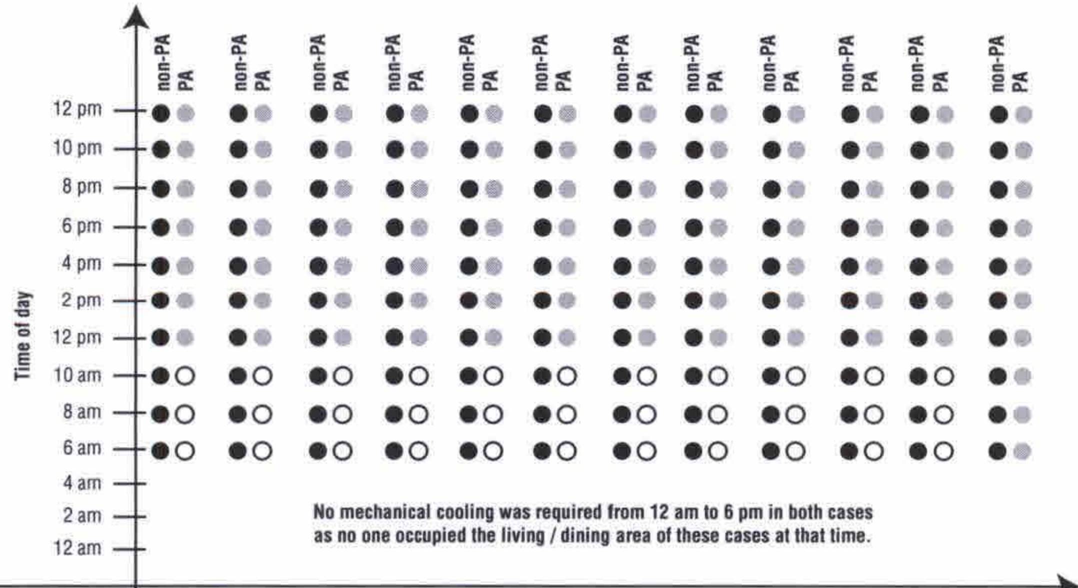


Figure 11: Use of mechanical cooling by PA and non-PA cases on 15th June.

thermal comfort zone during ante-meridiem (Table 4). It was also found that the indoor air temperature appears to be fairly consistent everyday because of the little climate change in the tropics. As a result, the daily Energy Savings Benefit from mechanical cooling claimed by the PA Case was consistently six hours

Table 4: Time and hours when the living/dining area of non-PA Case and PA Case had to rely on mechanical cooling on every 15th day of the month and the resultant Energy Savings Benefit (ESB) [marked as 'o'].



Month	Jan	Feb	Mac	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days	31	28	31	30	31	30	31	31	30	31	30	31
ESB/day	6	6	6	6	6	6	6	6	6	6	6	6
ESB/month	186	168	186	180	186	180	186	186	180	186	180	186

and that added up to 186 hours per month (i.e., 6 hours x 31 days) or 2190 hours (i.e., 6 hours x 365 days) per year.

Monetary value of Energy Savings Benefit from mechanical cooling

There are two typical methods adopted to bring down the indoor air temperature in the living/dining area into the comfort zone, i.e., using ceiling fan and air conditioning system. A typical ceiling fan has variable rheostat to control the rate of fan blade rotation. However, this has no bearing on the actual amount of energy use because when the fan speed is slow the excess energy is simply converted into heat (Mc Comas, 2008). Hence, the energy use by ceiling fan is either 'on' or 'off' and typical power requirement of a ceiling fan is 0.3kWh.

Typical domestic air conditioning unit of 1 horsepower uses 1.5 kWh of energy. 1K temperature difference in a room matters as far as indoor comfortable conditions is concerned because it affects the energy requirement for the air compressor. However this study did not differentiate the additional energy requirement for every 1K drop in temperature difference so as to generalise the findings. It was also assumed that a typical living/dining area of such size would need two mechanical cooling equipments serving each half of the space, i.e., either two ceiling fans or two air conditioning units. When using air conditioning units, the set point temperature remained at 28.6°C, being the upper limit of thermal comfort zone assumed in this study. Based on the above, the monetary value of one-year Energy Savings Benefit from mechanical cooling in PA Case was deduced to be RM 286.44 if used ceiling fan and RM1,728.36 if applied air conditioning system (Table 5).

Conclusion

The study showed that one-year Energy Savings Benefit from mechanical cooling and artificial lighting in PA Case could be up to 2190 hours and 1158 hours, respectively. When deduced into monetary value, one-year Energy Savings Benefit was recorded to be RM151.44 from incandescent lights and RM17.52 for EE fluorescent lights. Meanwhile, the monetary value of Energy Savings Benefit from mechanical cooling was found to be RM286.44 from ceiling fan and RM1,728.36 from air conditioning system. Therefore, it can be deduced that the maximum one-year Energy Savings Benefit claimed by the PA Case could be RM1,879.44, when compared to non-PA Case that used incandescent lights and air conditioning units. The study also found that substantial gain was due to the form and orientation of the PA Case and this was achieved without incurring any additional construction cost.

Although the demonstration was only for a living/ dining area of a house as an example of a building,

Table 5: Calculation of monetary value of Energy Savings Benefit (ESB) from mechanical cooling (ceiling fan and air conditioning unit) claimed by living/dining area in PA Case.

Item	**Calculation Description** Note: RM is Ringgit Malaysia TNB is National Electricity Board	2 units of Ceiling Fan	2 units of Air Conditioning Equipment
(A)	Energy required by mechanical cooling equipment	0.6 kWh	3.0 kWh
(B)	ESB per day = (A) x 6 hours	3.6 kWh	18 kWh
(C)	Average ESB per month = (B) x 365 days /12 months	109.50 kWh	547.5 kWh
(D)	TNB Domestic Tariff first 200kW @ 21.80sen/kWh/month	RM 23.87	RM 43.60
(E)	TNB Domestic Tariff next 800kW @ 28.90 sen/kWh/month	Not applicable	RM 100.43
(F)	Monthly value of ESB from mechanical cooling (D + E)	RM 23.87	RM 144.03
(G)	One-year value of ESB from mechanical cooling = (F) x 12 months	RM 286.44	RM 1,728.36

it could be generalised that when a property applies Passive Architecture design strategies it will indeed became less dependent on commercially supplied energy and consequently offered Energy Savings Benefit. In this case, the sample is in hot and humid tropics where buildings rely heavily on mechanical cooling. Together with the data recorded from the O&M experience, perhaps FM professionals could extend the idea of Passive Architecture into a wider context such as commercial and office buildings, etc. The research on Energy Savings Benefit could be extended to show favourable long term effect of Passive Architecture buildings, such as less mechanical and electrical installations to operate and maintain; and additional benefits to EE and RE installations – more so in the case of 'in-house' sourcing where building owner is also doing FM.

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