EVALUATION OF THREE ENERGY EFFICIENT OFFICE BUILDINGS ON ARCHITECTURAL AND PASSIVE DESIGN STRATEGY TOWARDS COST EFFECTIVENESS

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by

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Bismillahirrahmanirrahim. Alhamdulillah, finally, my research is complete. It is a great honour to conclude that supportive networks are also precisely the ingredients that made this work not only feasible, but greatly fulfilling.

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LIST OF ABBREVIATION

8th MP	Eighth Malaysia Plan
ASEAN	Association of Southeast Asian Nations
AC	alternating current
ACE	ASEAN Center for Energy
AKAA	Aga Khan Award for Architecture
ANV	Advanced natural ventilation
ASHRAE	The American Society of Heating, Refrigerating and Air Conditioning Engineers
BIPV	Building Integrated Photovoltaic
BMS	building management system
BRE	Building Research Establishment
C–C	centre-in centre out
C–E	centre-in edge-out
DC	direct current
DOE	Department of Energy
E&AS	Engineering and Architectural Services
E–C	edge-in centre-out
E–E	edge-in edge-out
EEMs	energy efficiency measures
ELCCA	Energy Life Cycle Cost Analysis
ESCOs	energy service contractors
GA	General Administration
GDP	Gross Domestic Product
GWh	Giga Watt-hour
HVAC	heating, ventilation, and air-conditioning
KeTTHA	Kementerian Tenaga, Teknologi Hijau dan Air
kWh/kWp	kilowatt-hour/ Kilowatt peak
kWh/m^2/year	kilowatt-hour/meter square/year
LEO	Low Energy Building
M	Meter
MECM	Ministry of Energy, Communications and Multimedia

MEWC	Ministry of Energy, Water and Communications
Mmbtu	Million British Thermal Unit
MS	Malaysia Standard
MW	Megawatt
NV	natural ventilation
OPP3	Third Outline Perspective Plan
OTTV	overall thermal transfer value
PETRONAS	Petroleum Nasional
PTM	Pusat Tenaga Malaysia
RE	Renewable Energy
RE	renewable energy
RICS	Royal Institution of Charted Surveyor
SC	Securities Commission
SESB	Sabah Electricity Sdn.Bhd
SREP	Small Renewable Energy Programme
TNB	Tenaga National Berhad
U.S	United State
UNDP	United Nations Development Programme
USM	Universiti Sains Malaysia
Wp	Kilowatt peak

PENILAIAN TIGA BUAH BANGUNAN PEJABAT BERKECEKAPAN TENAGA TERHADAP SENIBINA DAN STRATEGI REKABENTUK PASIF TERHADAP KEBERKESANAN KOS

ABSTRAK

Kekurangan sistem penyampaikan maklumat terhadap pengetahuan dan ciri-ciri teknologi bagi pemuliharaan tenaga, penghasilan dan penggunaan tenaga di dalam industri pembinaan telah membawa kepada penerbitan Standard Malaysia: Tata Amalan ke Atas Kecekapan Tenaga dan Kegunaan Tenaga yang Boleh Diperbaharui untuk Bangunan Bukan Kediaman (MS 1525:2007). Kajian ini telah dijalankan dengan merujuk kepada senibina dan strategi rekabentuk pasif yang tercatat di dalam MS 1525:2007. Penilaian terhadap perancangan tapak dan orientasi, rekabentuk permukaan bangunan, pengudaraan, lanskap strategik, dan pertimbangan masa hadapan terhadap tenaga yang boleh diperbaharui telah dibuat ke atas tiga bangunan berkecekapan tenaga terpilih iaitu Bangunan Suruhanjaya Sekuriti, Menara Mesiniaga dan Bangunan LEO. Bagi menilai tahap keberkesanan kos, kos bangunan untuk ketiga-tiga bangunan berkecekapan tenaga ini telah dibandingkan dengan kos bangunan tiga bangunan pejabat konvensional iaitu bangunan pentadbiran sekolah swasta, bangunan pentadbiran universiti swasta dan bangunan pejabat perniagaan. Penilaian ke atas kos bangunan dan kos penyelenggaraan juga telah dibuat seperti mana matlamat kajian ini adalah untuk membuktikan bahawa kos bangunan pejabat berkecekapan tenaga berkesan. Kajian kes telah melalui kaedah pemerhatian, temubual secara khusus, dan juga rujukan daripada kajian terdahulu. Kepentingan kajian ini adalah untuk memahami perkaitan antara rekabentuk, kecekapan tenaga, dan keberkesanan kos. Penemuan daripada penyelidikan ini menunjukkan bahawa, hanya bangunan LEO yang mengikut garis panduan sebagaimana tercatat di dalam MS1525:2007 dan berkesan dari segi kos berbanding bangunan-bangunan berkecekapan tenaga yang lain dan bangunan-bangunan konvensional.

EVALUATION OF THREE ENERGY EFFICIENT OFFICE BUILDINGS ON ARCHITECTURAL AND PASSIVE DESIGN STRATEGY TOWARDS COST EFFECTIVENESS

ABSTRACT

The lack of systems to disseminate information on the knowledge and technological characteristics of energy conservations, energy productions and energy usage in the construction industry has led to a publication of Malaysia Standard: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (MS 1525:2007). This study was carried out with reference to the architectural and passive design strategy stated in MS 1525:2007. The assessments to the site planning and orientation, facade design, ventilation, strategic landscaping and future consideration of renewable energy were made on three selected energy efficient office buildings which are Securities Commission Building, Mesiniaga Tower and LEO Building. To evaluate on cost-effectiveness, the buildings cost of these three energy efficient office buildings have been compared with three conventional office buildings which are Private School Administration Building, Private University Administrative Building and Commercial Office Building. The evaluations on building cost and maintenance cost also have been made because the aim of this research is to prove that energy efficient office buildings are cost effective. Case studies were made through observation, in-depth interviews and also references from previous studies. The importance of this study is to understand the relationship between design, energy efficiency, and cost-effectiveness. The finding from this research shows that, only LEO Building is almost followed all the guideline stated in MS1525:2007 and is cost effective compared to other energy efficient buildings and conventional buildings.

CHAPTER 1
INTRODUCTION

1.1 Research Background

The nature problem of the building energy demand has been recognised since the so called 'energy crisis' of the 1970s. Lately it is becoming increasingly crucial because of the impending exhaustion of fossil energy supplies. This situation has encouraged the biggest empire to 'the winning of the modern war'. Besides that, a lot of research and exploration has been developed to find new sources energy.

The recognition of the value of energy efficiency and its actual market implementation is still small in our country. The connection between buildings and energy efficiency has been acknowledged only in recent years in our country. This is due to the general lack of energy conservation awareness and eagerness to adopt new concept via technologies in a big volume within the Malaysian public.

In late 90s, the Malaysian Government tried to promote and develop energy efficient product. In 2004, Ministry of Energy, Water and Communication has developed Low Energy Office (LEO) building. It was designed as a showcase to demonstrate its energy efficiency and cost effective features.

There is also insufficient information disseminating system to create awareness in terms of knowledge and technological characteristics of energy conservation production and it use in the construction industry. Only in 2007, SIRIM Berhad, an appointed agency by the Department of Standards Malaysia has published the Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings (MS1525:2007).

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One of the purposes of MS1525:2007 is to encourage the design, construction, operation and maintenance of new and existing buildings in a manner that reduces the use of energy without constraining creativity in design, building function and the comfort and productivity of the occupants, and appropriately dealing with cost consideration.

Another obstacle for Malaysians to build energy efficient building is their apprehension that energy efficient office building cannot guarantee quick return of their investment. For example, businesses and consumers have shown their unwillingness to make investments with returns of 10 percentage – 20-year paybacks for businesses are often cited as the minimum for energy efficiency investments and consumers often make decisions that imply returns of 50 percentage or more. The lack of awareness and know-how are the other obstacles to investments in improving energy efficiency.

However, the regulation and practice of building design among Malaysians are willing to change. Up to now, there are a few government agencies that are really committed to this although a requirement of the energy efficient office building involves integrated analysis on its design. This is when it is designed with, sustainable, cost-effective, energy-efficient, and comfortable.

It is necessary having a well management of energy use and its expenditure. To deliver a successful energy efficient office design it requires spending the right amount of money and a diligent project team work.

1.2 Problem Statement

Cost uncertainty associated with new technology is likely to influence

decisions to build a building. Energy efficient building usually involves expensive technology. Therefore, it influences the decision to build it. The technology that is imported from developed countries is generally more expensive than the one that is manufactured locally. This can be due to the higher labour costs and higher quality standards prevailing in the former. In Malaysia, we do not manufacture photovoltaic or solar panel system.

Nevertheless, the awareness on the exhaustion of energy supplies shall encourage designers to settle this crisis by, firstly, designing building for service system with maximum energy output or minimum/zero energy wastage. Secondly, design building for maximum utilization of passive technologies, i.e. daylighting and natural ventilation, office building to provide physical comfort and minimum energy consumption. Thirdly, harness more powerful forms of energy efficiency to achieve the greatest possible economic benefit. And, lastly, create aesthetic and functional designs elements which make everyday life easier and more enjoyable, provide an effective and safe interaction between workers and office environment.

All building designs require proper cost analysis to estimate the right value of all the building elements. Without a proper guidance, energy efficient building design cannot be achieved at a reasonable cost. Questions such as “Can the initial cost of the energy efficient building be recovered within short payback periods?” should be address carefully. Lack of available information regarding the associated cost of energy efficient design, appropriated technologies and applications may lead to unsuccessful design decision.

1.3 Research Aim

Due to the unreliability of information provided to the potential builders or buildings owners about energy efficient office building especially on the market potential, the researcher hopes that this research will increase a willingness and ability on the part of the building owner to pay more for the initial cost. Therefore, the aim of this research is to prove that energy efficient office building is more cost effective compared to the conventional office building.

1.4 Research Objectives

The aim of this research would be achieved through the following objectives:

i) To identify the design criteria for energy efficient office building in Malaysia which are able to minimize energy cost.

ii) To study and evaluate architectural and passive design strategy those have been use in energy efficient office buildings in Malaysia.

iii) To assess whether energy efficient office buildings are more cost effective than conventional office buildings.

1.5 Research Methodology

The case study will be carried out based on the vertical framework devised from literature review on several related works done by previous researchers. The primary data will be obtained from survey and observation study and data from the buildings' owners and professional bodies regarding records.

1.6 Scope of Study

This research will focus on the issues of energy efficient office building which will emphasise on the architectural and passive design strategies in order to minimise

the dependence on fossil energy. The study will focus on three energy efficient office buildings in Malaysia. The office buildings included government buildings and private buildings. Moreover, project cost in general shall be the guideline for the researcher to know whether energy efficient office building can benefit the owner and give the best form of cost effectiveness.

1.7 Significant of The Research

i) This study can provide the momentum for securing cost-effectiveness to building owners or occupants toward energy efficient office building. A result for this research can be used as guidance for maximising economic outcome for the new office building.

ii) Besides that, the result from the analysis on strategy of passive design and architectural which are related to the cost-effectiveness will boost the developers' confidence and building owners to build energy efficient buildings in future

1.8 Summary

This chapter has laid the foundations for the thesis. The chapter was started by the background of the research, followed by the research's problem statement. Then, it looked into the research aim, objectives, methodology used, scope of study, and lastly the significant of the research.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The aim of this chapter is to review the architectural literature on the concept of energy efficient office building and related information in order to identify which criteria are able to minimize cost and to access whether energy efficient office buildings are more cost effectiveness then conventional office buildings.

The review begins with the current situation of energy demand, the definitions and the terms of existing building types nowadays. A clear definition will guide to understand the concept of energy efficient office building in order to achieve the objectives of this research.

2.2 Energy Conservation and an Overview of Energy Industry in Malaysia

According to The Star, 3rd July 2004, "The local power sector is currently one of the country's most highly subsidised industries. Since 1997, the price of natural gas has been fixed at RM6.40 per mmbtu. This represents a 76 percent discount to average US rates of US$6.39 per mmbtu converted at the prevailing exchange rate. Thus far, the discount has been borne by Petroleum Nasional Bhd (Petronas) in the form of loss of revenue." (Chan, 2004).

The Minister said, from 2000 to 2008, the Government has spent RM61.95 billion to subsidise electric sector (KeTTHA, 2009). In early June 2008, the Government announced the restructuring of fuel subsidies amidst the continuing escalation in oil prices globally. As local power sector is currently one of the country's most highly subsidized industries, Malaysian government claimed that they

cannot fully support the Malaysian for fuel increment due to global market increment. Subsequently, the prices of gas supplied by Petronas in Peninsular Malaysia also were increased on 1st July 2008.

The electricity price was up for review in 2000 (following the expiry of the Gas Supply Agreement) when Petronas started pushing hard for an upward revision. In the end, the rate was maintained as any increase would be detrimental to TNB (The utility company has not seen a tariff increase since 1997 when the average rate increased by 9.5 percent to 23.5 percent per kWh). Then, the gas price was scheduled for its review at the end of 2005. On 1st of June 2006, the Government had approved an average of 12 percent increase in the electricity tariff of TNB. On 1st of July 2008, the Government had approved an average of 24 percent increase in the electricity tariff of TNB. The increase was to cater for the fuel cost (gas and coal) increase due to the restructuring of gas subsidies by the Government and the global escalation of coal prices. Eight (8) months after that, the Government decided to reduce the electricity tariff about 3.7 percent in average due to the current deduction of gas price.

According to Energy Commission Malaysia (2005) during the past two decades, demand for commercial energy grew rapidly, increasing at an average rate of 7.5 percent in the 1980s and 7.7 percent in the 1990s, surpassing the Gross Domestic Product (GDP) growth of 5.9 percent and 7 percent over the corresponding period. The peak demand for electricity registered a steady growth during the 2001-2003 periods. Peak demand grew at a rate of 5.8 percent per annum, reaching 12,637 MW in 2003. To meet the growth in peak demand, the electricity generation capacity

was increased to 18,562 MW by 2003. The bulk of the capacity expansion was in Peninsular Malaysia.

The electricity demand of Malaysia will increase by 4.7 percent per year over the outlook period, to reach 274 TWh in 2030. The growth in electricity demand is heavily influenced by strong demand from the industrial sector, which is projected to increase at 5.4 percent annually over the outlook period. Electricity demand for the residential sector will also experience strong growth of 4.9 percent per year due to improving living standards. Per capita electricity demand is projected to more than double from 2002 to reach 7,571 kWh/person in 2030, higher than that of the APEC region average at 6,833 kWh/person.

In 2002, Energy Commission Malaysia had conducted a research on the 987 m^2 single storey office. The finding is; that office building consumed 232,050 kWh and giving it an energy consumption index of 235 kWh/m^2/year. The breakdown was 64 percent for air conditioning, 12 percent lighting and 24 percent general equipment. This statistic shows that most office buildings in Malaysia use the electricity for the cooling systems. If we can reduce the air conditioning usage to 14 percent, we can reduce the energy consumption index to 117.5 kWh/m^2/year. If we make a use of natural lighting during day time, and reduce another 10 percent of lighting usage, the energy consumption index can be reduce to 94kWh/m^2/year. To set the energy consumption index at 100kWh/m^2/year and below, designers must design the buildings by utilising natural lighting and natural ventilation without sacrificing human comfort.

Table 2.1 *Price* List for Gas Subsidy
Source : Petronas (2006)

GAS SUBSIDY
Increasing Subsidy due to Higher Volume and Price

PETRONAS

In RM Billion

Gas Subsidy	FY2008	+/-	FY2007	Cumulative subsidy since 1997
POWER SECTOR	**13.8**	**17.9%**	**11.7**	**62.6**
- TNB	5.7		5.0	26.9
- Independent Power Producers (IPPs)	8.1		6.7	35.7
NON POWER SECTOR – including small industrial, commercial, residential users and NGV	**5.9**	**51.3%**	**3.9**	**15.3**
TOTAL GAS SUBSIDY	**19.7**	**26.3%**	**15.6**	**77.9**

Gas Price to Peninsular Malaysia Customers

	Before Subsidy Restructuring Package		After Subsidy Restructuring Package		Market Price (as at 11 July 2008)		Subsidy Element
	Fuel Prices	RM/mmbtu Equivalent	Fuel Prices	RM/mmbtu Equivalent	Fuel Price	RM/mmbtu Equivalent	
Gas Supply to Power Sector	RM6.40/mmbtu	6.40	RM14.31/mmbtu	14.31	RM63.17/mmbtu	63.17	RM48.86/mmbtu
Gas Supply to Large Customers	RM11.32/mmbtu	11.32	RM23.88/mmbtu	23.88	RM86.26/mmbtu	86.26	RM62.38/mmbtu
Gas Supply to Gas Malaysia Sdn Bhd	RM9.40/mmbtu	9.40	To be determined		RM64.99/mmbtu	64.99	To be determined
LPG	RM1.75/kg	37.39	RM1.75/kg	37.39	RM3.84/kg*	82.04	RM2.09/kg
NGV	RM0.68/litre	20.86	RM0.68/litre	20.86	RM3.22/litre	98.77	RM2.54/litre
Diesel (transportation sector)	RM1.43/litre	38.65	RM1.43/litre	38.65	RM3.80/litre*	102.70	RM2.37/litre
Diesel (fishery sector)	RM1.00/litre	27.03	RM1.43/litre	38.65	RM3.80/litre*	102.70	RM2.37/litre
Diesel (pump price)	RM1.58/litre	42.73	RM2.58/litre	69.73	RM3.82/litre*	103.24	RM1.24/litre
Petrol (pump price)	RM1.92/litre	58.90	RM2.70/litre	82.82	RM3.36/litre*	103.07	RM0.66/litre
Fuel Oil	-	-	-	-	USD117.50/barrel	60.74	-
Coal	-	-	-	-	USD208.00/MT		-

** According to Automatic Pricing Mechanism (APM)*

Efforts are also undertaken by the Government to promote the utilization of Renewable Energy (RE) in power generation. In our fuel diversification strategy, RE was introduced as the fifth fuel in an effort to reduce Malaysia's dependence on fossil fuels. A Small Renewable Energy Programme (SREP) was launched in 2001 to intensify the development of RE as the fifth fuel in electricity generation. Under this programme, small power generations plants (10MW) and below) have been developed which utilities RE can apply to sell electricity to Tenaga National Berhad (TNB) and Sabah Electricity Sdn.Bhd (SESB) through the distribution grid system.

2.2.1 National Energy Policy Objectives

According to United Nations Development Programme (2004) and Chan (2004), there are three principal energy objectives are instrumental in guiding the future energy sector development. Malaysian government have driven these three key energy policy objectives in the 1980s because they recognize the importance of the energy availability to stimulate economic growth. Malaysia's 5-year development plans are formulated primarily on these policies, which play a crucial role in the government's planning for a sustainable energy system. The main objectives of the national energy policy are as follows.

a) The Supply Objective:

To ensure the provision of adequate, secure and cost-effective energy supplies through developing indigenous energy resources both non-renewable and renewable energy resources using the least cost options and diversification of supply sources both from within and outside the country;

b) The Utilization Objective:

To promote efficient utilization of energy and to discourage wasteful and non-productive patterns of energy consumption;

c) The Environmental Objective:

To minimise the negative impacts of energy production, transportation, conversion, utilisation and consumption on the environment.

2.3 Energy Efficiency and Building: The Definitions and The Terms

Principally, energy efficiency is not energy saving. Energy efficiency means using energy efficiently to save energy usage from being wasted. According to Maznah (2003), she defined that energy efficiency in simple words means the extraction of maximum energy out of fuel or less energy wastage. This can be achieved by the use of efficient equipments, system or plants. Efficient use of energy will help to reduce energy consumption, hence will cause less emission. Energy efficiency can be applied in energy production, distribution and utilization in many areas such as power plants, and in sectors like industrial, transport, commercial and residential.

Recently, they have come out with many terms and approaches for the office building concepts. The terms ‘energy efficient office building’, ‘high-performance office building’ and ‘intelligent office building’ appear similar but most people are still defining and quantifying what these terms really mean. The words look fashionable and parallel but the ideas, concepts and objectives can be assumed to achieve a target of ‘design optimization’. Although there is no specific definition about design optimization in architecture, but design optimization can be related to

the concept of excellent design. The concept of design excellence in the context of building construction is to design ambitiously, carefully and with serious investigation into all elements of the building structures. In the context of energy efficiency, a phrase 'design optimisation' can be understood to create or design the building which can optimize the usage of energy without any wastage. This statement has a close relationship to the definition above which is given by Maznah (2003), *"....energy efficiency simple words means the extraction of maximum energy out of fuel or less energy wastage..."*

2.3.1 Energy Efficient Building

According to Maznah (2003), she clarified that energy efficient buildings are those that provide the specific internal environment with minimal energy cost, normally within the constraint of what is achievable cost-effectively. This can be achieved by using innovative materials, technologies and design concepts as climatically optimized architecture is being developed to reduce the unnecessarily high-energy consumption in buildings while retaining the same level of comfort.

Maznah (2003) explanation can be strengthened with the U.S Department of Energy (2003) statements. They defined that energy efficiency means using a building's individual components to do the same job as less efficient components for less money over the long-term. Energy efficient office building components applies to everything from the building envelope, which includes energy efficient windows, lighting, insulation, foundation, and the roof, to office equipment that does not waste energy sitting idle and equipment with built-in power management features. It also applies to space heating and cooling, which are aided through the use of automated controls, ventilation, improved duct systems and other advanced technologies.

Energy efficiency can also apply to water heating when combined with water-efficient appliances and fixtures that will save water, energy and money.

Pusat Tenaga Malaysia (2006) uses the term of energy efficiency in building to classify this kind of building. They define that energy efficiency in building means using less energy for heating, cooling and lighting. It also means buying energy-saving appliances and equipment for usage in a building. The important concept for energy efficiency in buildings is the building envelope, which is everything that separates the interior of the building from the outdoor environment: the doors, windows, walls, foundation, roof and insulation. Various approaches could be done to improve the building envelope. For instance, windows with special glazing can let in sunlight without heat gain and storm windows and doors can reduce heat loss when temperatures drop. These techniques can significantly improve a building's energy efficiency.

From these sources, energy efficient buildings can be concluded as a building which establishes its performance goal from the start for occupancy, cost saving, comfortable and good indoor environment quality in order to achieve its objective - minimizing energy consumption.

2.3.2 High Performance Building

Eley (2006) mentioned that high performance building is synonymous with a green building or a sustainable building. According to National Laboratory of the U.S Department of Energy (1999) a high performance building is a building that uses whole-building design to achieve energy, economic, and environmental performance that is substantially better than conventional practice. Whole building design creates

energy efficient office buildings that save money for the owners. This process also produces buildings that are healthy places to work. It helps to preserve natural resources and can significantly reduce a building's impact on the environment.

This whole-building philosophy considers the site, energy, materials, indoor air quality, acoustics, natural resources and the integration of all these criteria. This approach brings together building design, energy efficiency and today's solar technologies to boost energy savings and make the most of all building's elements. It reduces the amount of energy required to operate a building compared to conventional buildings. It improves the comfort of building occupants by using pleasing architecture designs to brighten up work areas using sunlight rather than electricity, without causing excess glare (U.S. Department of Energy, 2006).

Some building designs carry the meaning by recreating a feeling remembered from other time and place such as a great civilization of Islam, Greek and Rome. According to Yang Mian in her essay, *'Ideal Building Standard'* in 2000 she emphasized that the modern architecture almost tries to show attraction by the cultures within the societies and the adaptation of their civilization. These designs can be seen in a few office buildings in Malaysia. For example, PETRONAS Twin Towers, the world landmark in Malaysia, were designed to symbolize strength and grace using geometric principles typified in Islamic architecture.

Eley (2006) viewed that a high performance building is a good building, meaning that the building performs its function well and uses resources efficiently. High performance building is a first class place which is comfortable and healthy for occupants to work and perform productively.

From the explanation above, it can be concluded that high performance building is a building which represents an icon for any civilization. This kind of building is not only adorable and beautiful but also fulfils the characteristics of excellent designs that is it planned, generous, robust and make good use of natural environment. Furthermore, it shall be beautiful in composition and act as a backdrop to everyday human activity. Energy efficient office building is a part of the criteria of high performance building.

2.3.3 Intelligent Building

The concept of intelligent building occurred in early 1980s. The definition of intelligent building has been evolving with different emphasis, mainly driven by the development of relevant technologies and the changing needs for the built environment. It started when people required a building which is automatically monitoring and controlling the devices such as fire alarm, air conditioners, lifts, lighting systems, CCTV etc in buildings via Intelligent Building Management System (IBMS) or Building Automation System (BAS). The idea is basically to enhance the quality of comfort, security and productivity.

Ehrlich (2005) defined that intelligent building is a building that makes use of technology and process to create a building that is safer and more productive to its occupants and more operationally efficient to its owners. He added that intelligent building is a building that environmentally friendly and energy efficient ties in closely with many of the intelligent attributes. He also summarized that intelligent buildings are designed for long-term sustainability and minimal environmental impact through the selection of recycled and recyclable materials, construction, maintenance and operations procedures. Providing the ability to integrate building

controls, optimize operations and enterprise-level management results in a significant enhancement in energy efficiency, lowering both cost and energy usage compared to non-intelligent projects.

While CABA (2008) has defined intelligent buildings which refers to integrating the low-voltage, signal, data and communication systems into one network. Integrating systems into one network can help the buildings to offer the ability to rapidly control and automate the system such as life safety, building management, security, elevator controls and office telecommunication.

Intelligent buildings are intended to be the best environments for modern occupancy. The reason is because these buildings require focused attention to environmental factors that affect occupants' perception, comfort, and productivity. An intelligent design strikes the balance by providing a superior indoor environment and minimizing energy usage and operating labour. This is where the technology becomes valuable.

From the above statements and definitions, intelligent building and energy efficient building are different because their objectives are clearly difference. For example; in term of operation, the objective of energy efficient building is to achieve energy efficiency in building operation; where intelligent building is to let the building system operating smartly.

2.4 Overview: Office Building

A common perception of office building is a place or building where people work. It often constructed on a large scale and contains a massive of amount space. Offices can be built in almost any location in almost any building; some modern

requirements for offices make this more difficult. These requirements can be both legal (light levels must be sufficient, for example) or technical (requirements for networking). Alongside such other requirements such as security and flexibility of layout, this has led to the creation of special buildings which are dedicated only or primarily for use as offices.

The professionals who are involved in the construction industry are responsible to create a good environment in a workplace. Designers and planners contributions are very important to make sure natural resources are being used in a good way. They should constitute an attempt to reconcile the imperatives of production and consider the workers need.

The primary purpose of an office building is to provide a workplace and working environment primarily for administrative and managerial workers. These workers usually occupy set areas within the office building, and usually are provided with desks, personal computers and other equipment they may need within these areas. An office building will be divided into sections for different companies or may be dedicated to one company. In either case, each company will typically have a reception area, one or several meeting rooms, singular or open-plan offices, as well as toilets.

Today, office buildings are expected to provide a comfortable environment for the occupants, to compensate for abstraction of work and safeguarding workers from stress, unifying the organization and expressing its values and organization, motivating and mobilizing the staff, promoting sociability and co-operation and reflecting a company's desired image. Human lifestyles have changed compared to the last century. Conway (2009) mentioned that, America, northern Europe and

Japan, at least 50 percent of the working population spends the workday in office buildings and spaces, and employers today are increasingly bearing the responsibility of providing a quality compared to 5 percent of the population at the beginning of the 20th century.

To succeed in this situation the employers offer to increase workers satisfaction and productivity, improved health, greater flexibility and enhanced energy (energy efficiency) and environmental performance. It requires a life-cycle analysis to optimize initial investment in architectural design, building system selection, and building construction.

Binggeli and Corky (2003) pointed out that energy-efficient technique sometimes necessitate special equipment or construction, and may consequently have a higher initial cost than conventional designs. However it is often possible to use techniques that have multiple benefits, spreading the cost over several applications to achieve a better balance between initial costs and benefit.

To design office building, several guidelines applied nowadays can be used as references in the planning stage. For example *Malaysian Standard: Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings MS1525:2007*. A definition of energy efficient building reviewed before and the criteria below can give some ideas and guideline for the project team to design energy efficient office building.

2.4.1 Criteria of Energy Efficient Office Building

a) Using Passive Device

The idea of energy efficient office building is to reduce the energy consumption inside the building and create a comfortable environment for work place. Energy efficient office building will implement the most cost-effective solutions those can maximize office building performance and minimize energy waste. Passive design will help in creating healthy indoor environments and give a personal comfort to the workers.

Energy efficient office building uses devices to maximize daylight, natural ventilation and reduce a need for mechanical devices. These mechanisms can reduce the adverse environmental impacts of pollution generated by energy production and this office building considered to be the cornerstone of sustainable design.

Rather than to reduce a need for mechanical devices, the objective of energy efficient office design is also outperform conventionally designed office building in many ways including heating, lighting and ventilation. The most important is; it can minimize the operation cost and energy cost. The first step is; the project teams must consider the aspect of site planning and orientation of the building.

b) Whole Building Concept

The key in understanding building performance as a whole is to understand and maximize integration among the various building systems. Begin by carefully and systematically reducing the overall building loads such as heating and cooling (thermal pressure), wind pressure and rain pressure. This is how the building owner can reduce operation costs and first capital costs. When all loads have been lowered,

then look at mechanical systems. Mechanical systems more expensive compare to passive system.

The integrated approach can be related to the concept of design optimization. It is also similar to the whole building concept. When refers to Young (1986), he emphasized that, optimization of space means that there is to be no waste of space in the building and any unused space must be kept to a minimum. Radford and Gero (1988) clarified that design is one of the highest endeavours to which we can aspire: the making of unambiguous proposals to reshape our environment to make it better suited to men's and women's needs (Radford and Gero, 1988). The concept of design optimization for this study conveys the idea of balance, of harmonic, of dynamic symmetry, of honest expression of the size of structural elements and in general, of a pleasing and satisfying wholeness, such as we often are able to recognize in other art. For the result, design optimization should fulfil the goal of instilling in every creation a personally meaningful quality, expression the fitness and functional through the broadest range of usefulness to the human occupants. Design optimization links the desire for good performance in the goals to the decisions that result in good performance (Radford and Gero, 1988)

Energy efficient office building is an office building which is designed by adapting the concept of integration. Energy efficient office building design is not just the result of applying one or more isolated technologies. Rather, it is an integrated whole-building process that requires advocacy and action on the part of the design team throughout the entire project development process. The whole-building approach is easily worth the time and effort, as it can save energy costs over a conventional building designed.

According to US National Renewable Energy Laboratory (2006), systems and components that are designed to work well together are building orientation, heating and cooling systems, insulation, lighting, and windows. A systems integration approach enables advanced technologies to function more efficiently while still meeting the challenging reliability and cost requirements for buildings. In retrofit application, advanced technologies can provide the best opportunities to increase energy efficiency in the buildings.

2.4.2 Conventional Office Design

Conventional office building is an office building which is used a custom design process. It function is more specific for workplace. In the context of energy efficiency, conventional office building is a building which is designed with less consideration of passive design or less concern to minimise the usage of electricity. It can be a simple office block which is rectangular shape or a building that is rich with art as it is reflected from a human activity, place or time but less consideration to minimise energy consumption. Most of office buildings nowadays are just the designers' inspirations which are translated from clients' requirement; beautiful designs.

Researcher has categorised conventional office buildings into a few categories. Some are just rectangular blocks which enclose many partitions for administrative activities. Some of conventional office buildings are more concerned on their appearances where the designers created a pure enchantment to the buildings' performance to make the occupants feel in high spirits. They may concern about the texture and colour, light, sound, layout and pattern, shape and line and also its scales but they less concern on the aspect of energy efficiency.

In the country like Malaysia, where the weather is hot and wet through the year, most of office buildings are designed with the enclosed spaces. According to Koenigsberger et.al (1978) he also mentioned that in warm humid tropics countries, buildings are designed without allowing direct sunlight to enter the interior of the building to avoid heat. Furthermore, enclosed space is very important for air-conditioning system to work efficiently because opening can cause air (cool air) leakage.

At times, judgment on office building may be good because people feel it follows current design trends, reflexes ancient cultural, it is in fashion or it enhance a status. Office design consultant and author, Francis (1995) has mentioned that, "The office building is one of the great icons of the twentieth century. Office towers dominate the skylines of cities in every continent". But, in the context of energy efficiency, beautiful designs do not give any significance if the buildings fail to save energy usage from being wasted.

2.5 Architectural and Passive Design

According to Chan (2004) the building layout, planning, design, shape, fabric and construction cover a wide number of variables that affect building energy requirements. Passive design is a basic decision of the architect will have the most influence on the building's energy use. Refer to MS1525:2007, passive design strategy is applied when the design and construction of a building takes optimal advantage of its environment need and it does not impose any significant extra cost as compared to a more highly serviced building. The architectural consideration in

designing a building is influenced by its responsiveness to the immediate environment. The important factors that should be considered include the following:

a) Building orientation;
b) Building configuration (geometry and layout);
c) Effective room depth;
d) Floor to ceiling height;
e) Location of cores;
f) Building façade;
g) Internal layout;
h) Fenestrations;
i) Building materials;
j) Roof design and colour, and
k) Landscaping and shading.

These factors are just as important as the selection of systems or devices to control lighting and thermal comfort (cooling) within the building. Sub-topics below will elaborate based on the above reference.

2.5.1 Factors Affecting Building Design for the Climate of Malaysia

Building acts as a shelter to the habitats. Basically it was designed to suit with the human comfort. Malaysia is a warm-humid climate country. According to Koenigsberger et. al (1978), buildings in warm-humid climates are typically of lightweight construction, with large openings to ensure sufficiency cross-ventilation and air movement, usually with wide over-hanging eaves or other shading devices. Direct sun light is excluded for thermal reasons. The sky is bright, could provide sufficient light, but its high luminance would also cause glare.

For this reason, view towards the sky should be screened by shading devices or plants. The foregoing establishes rather specific requirements for the design of shading devices. The criteria, far more stringent than just the exclusion of sunlight, can be summaries as below;

a) permit view of sky and ground near the horizon only, within +/- 15° (up and down)
b) exclude view of bright ground and sunlit blade or louver surfaces
c) day light is to be reflected from ground and blades up to the ceiling, which itself should be of a light colour

2.5.2 Nature of the climate

The most prominent characteristics of this climate are the hot, sticky conditions and the continual presence of dampness. Air temperature remains moderately high, between 21°C and 32°C, with little variation between day and night. Humidity is high during all seasons. Heavy cloud and water vapour in the air act as a filter to direct solar radiation; it is thus reduced and mostly diffused – but clouds also prevent re-radiation from the earth at night. Moisture in the air combined with moderate heat and high rainfall is favourable to the growth of vegetation. The plant cover the ground reduces reflected radiation, and lessens the heating up of the ground surface. Winds are generally of low speed, variable in speed, but almost constant in direction (Koenigsberger et. al, 1978).

2.5.3 Orientation and Planning

An important clue in developing energy efficient facades is the knowledge about the distribution of solar radiation due to orientation. Until recently detailed

studies on solar radiation were primarily carried out in the area of solar energy systems, trying to maximize the solar harvest (Friedrich and Michael, 2006).

The building plan (site planning), in addition to responding to the commercial intentions of the building (for example, enabling single, double or multiple tenancies), should reflect the patterns of life and culture of the place, and its climate. In part this involves an understanding of the spatial modalities of the people, the way they work, the way culture arranges privacy and community (Yeang, 1995).

Site planning has a relationship with orientation when refer to Yeang (1995) statement's, *"This can be reflected, for example, in the plan configuration, the building's depth, the position and layout of entrances and exits, the means of movement through and between spaces, the orientation and views as interpreted in the plan. The plan should also reflect air movement through the spaces and the provision of sunlight into the building"*.

The orientation of the building should be accumulated with sun path. Sun path is the sun's position on the sky hemisphere (Koenigsberger et.al, 1978). It can be specified by two angles:

a) Solar *attitude angle* (y). e.i. the vertical angle at the point of observation between the horizon plane and the line connecting the sun with the observer.
b) Solar *azimuth angle* (a). e.i. the angle at the point of observation measured on a horizontal plane between the northerly direction and a point on the horizon circle, where it is intersected by the arc of a vertical circle, going through the zenith and the sun's position