CHAPTER 2.0

Background Study

In earlier days it was understandable that the principle for the existence of a building is the need to create a better environment for people to live in as Fathy, (1986) said:

> *"Early men built houses to keep out the impact of negative environmental elements such as –rain, wind, sun and snow. Their purpose was to produce an environment favourable to their comfort and even to their survival."*

This statement showed there is a relationship between building and climate in any traditional architecture design, their physical and characteristic demonstrates the architecture of particular region.

Buildings come in wide amount of shapes and function. They serve several needs of society-primarily as general living space and as shelter toward unfavourable weather and to provide privacy, to store belongings and to comfortably live and work.

> *"A building as a shelter represents a physical division of the human habitat into the inside (a place of comfort and safety) and the outside (a place that at times may be harsh and harmful). External environment, internal environment, people's responses and the building fabric are interconnected and these four categories interact in a complex way."*
>
> (Lippsmeier, 1969, pp15)

However, many designers and developers nowadays tend to be more emphasized in building aesthetic and profit rather than the comfort of occupants based on studies done by Abdul Malik (1994). There is a strong foothold of modernity in Asian city today. *“Copying what is ‘new’ and ‘modern’ has become an obsession for which there is no remedy.”* writes columnist Calloway (1991). This indicated that copying Western architecture as a symbol of modernization has become common among Asian. Design that suited temperate climate may not necessary suit tropical countries such as Malaysia. However, many buildings in Malaysia directly adopted the design and construction of temperate climate; for example, the use curtain walling which increases the risk of thermal discomfort for the occupants and reduce the thermal performances of the building. Air conditioning for ventilation becomes a standard solution to deal with this extra discomfort due to extra heat gains. Currently typical contemporary houses consume double of the primary energy compared to naturally ventilated and day lit conventional buildings as per stated in studies done by Gupta (1992).

In tropical countries, where the dependence on cooling systems especially air conditioning increase in tandem with economic growth, there are growing concerns over future global environmental problems and a possible drain on energy resources.

> *“With the increased of energy bills, residents have increasingly expressed dislike of modern residences which rely on air conditioned or solar control films to cool down the buildings. Besides that, these ‘sealed’ buildings have often associated with sick building syndromes. Occupants are now demanding greater control of their living conditions, and the recent launch*

> *of the Green Building Index showed the government is aware that there is a connection between living conditions and productivity."* (Kwok, 2007)

"In the 1990s, concern about global warming has resulted in a resurgence of interest in naturally ventilated buildings." (Wright, 1991) These concerns are giving more thought to the design of windows and types of glazing, natural ventilation and day lighting are in demand in order to achieve energy saving in building with additional challenge on how to filter out traffic noise in urban areas. When designing a naturally ventilated building, there are many old buildings that are worth to be reviewed as precedent studies. These old buildings were designed to be climate responsive as air condition has not invented during that period based on studies done by Ghafar (1997).

However, many of these old buildings which located in urban set up especially at prime area had been replaced with high rise buildings in the name of development. Old buildings should retain as to educate our future generation. Conservation depicts restoration of the past and preservation of the future. Conservation is the most important engineering understanding to develop the observational exposure so as to decide when not to touch the structure. In the context of old buildings, Rai, (1992), Kennedy, (1962), Feilden, (1982), Raikar, (1999) and Harvey, (1972) has categorised conservation into three subgroups of activities, there are:

> *"Preservation – which is maintaining the equilibrium with or without intervention, with normal repairs and routine maintenance as required periodically. Restoration – which means major structural intervention for*

repairs to foundations, column, masonry, and roof in some cases total rebuilding may be clone to some elements in parts or areas of structures. Rehabilitation – refers to the aspect of reuse of some building materials may be some new one to match with original or an appropriate alternative use." (Raikar, 1999)

It is crucial to investigate these old buildings before they disappeared as they should have many characteristics which led to thermal comfort, it could be the shape of the building and elements of the building, (e.g., indoor spaces, doors, windows etc) the local context and orientation in order to take maximum advantage of the climate. Landscaping and water played a big role in cooling the air. Therefore, the design concepts employed in the heritage buildings should be rediscovered. Features that are suitable to contemporary urban settings could be extracted and utilized in contemporary architecture.

2.1 Thermal comfort & Acclimatization

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE, 1985) defined thermal comfort as *"a condition of mind which expresses satisfaction with the thermal environment"* (ISO 7330) and according to D Watson, (1983) & Hyde (1997) thermal comfort is *"A controversy between the heat-balance approach and the adaptive approach has dominated the development of thermal comfort science. Housing in the United Kingdom is improved to provide a basic standard of ventilation and warmth"*. However the international standard for thermal comfort condition, has been determined by the World Health Organisation (Straatan, 1988), which are temperature of 21°C for people in a living room and 18°C elsewhere in the home. (Auliciems and Szokolay, 1997, pp. 56) but according to Wong (2003), De dear (1991) and Busch (1990) thermal comfort level that has been determined by respondents in Malaysia is in the range of 26°C- 30.7°C. These standard requirements have become a primary policy which challenge and involve the building designer in improving housing conditions so that basic physiological needs are met. Comfort emerges as a factor in high energy consumption.

"Surveys of over 500 homes at Twin Rivers in the eastern USA showed that homeowners' summer electricity consumption could best be predicted by comfort and health concerns (Rai, 1991)". The greater the importance of personal comfort and 'health' to the household, the higher the consumption for air-conditioning was likely to be.

Indoor thermal comfort within building is primarily controlled by four major factors: air temperature, mean radiant temperature, humidity and airflow where each of them can have a dominating effect. There are other factors which affect thermal comfort including clothing, activity level of the occupants and their acclimatization. Some psychological triggers, such as certain colours, also seem to affect thermal comfort, and 'state of mind' can have major effects on individual comfort sensations. *"Comfort zones are very generally defined as the zone in which 80 percent of the population will experience the sensation of thermal comfort."* (Carmona, 1984, pp. 234)

> *"Technological and cultural pressures (eg building design, dress codes, heating and cooling control systems) are in danger of producing convergence on a very limited range of temperatures that are perceived as*

'comfortable', particularly in public buildings such as offices" (Khedari, 2000)

This implies both the increase of indoor temperature control and energy use. For example, an individual is likely to dress in the morning with the anticipation of the indoor climate in the workplace and may try to replicate this climate when she or he returns home in the evening.

2.1.1 Thermal comfort principle

Studies showed that human body responses to environmental condition. According Auliciems, (1997),

> *"The human body constantly generates excess heat. This is accomplished through the metabolic process where food is converted to body energy through digestion. This energy is in turn used to perform useful work and as a by-product, heat."*

The amount of heat produced by the body is proportionate to the level of activity, where higher levels of activity will generate higher levels of thermal energy. Since humans are warm-blooded mammals, the body needs to lose this excess heat so deep body temperatures will remain relatively constant at 37°C (98.6°F) in order to prevent serious medical complications. In the opposite scenario, if the environment is very cold the body will involuntarily shiver-work which produces more body heat to keep deep body temperatures at their required levels. Similarly, the body has numbers of mechanisms to dissipate heat when the environment is overheated as Hasegawa (1983), Szokolay (1999) and Wilson (2005) said: *"The human body exhibits all normal heat transfer mechanisms (conduction, convection and radiation) in addition to the rather remarkable ability to perspire and cool itself by evaporative heat loss."*

"As air temperature approaches the skin temperature 33°C-34°C (92°F-94°F), most body heat loss must occur through evaporation." If the air has a high relative humidity, the potential for evaporation to take place is greatly reduced because the air cannot easily absorb more moisture. Theoretically, when the relative humidity reaches 100% and the air temperature exceeds skin temperature, the body can no longer evaporate moisture or convective heat away from itself and the potential for very serious and even terminal body overheating exists (i.e., heat stroke).

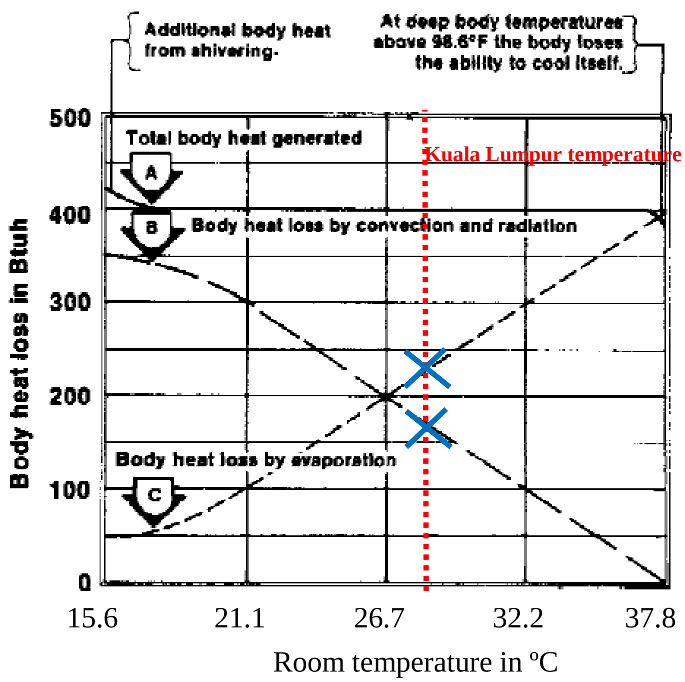

Figure 2.1: Body heat loss and air temperature
(Source: Szokolay, 1999)

In referring to the average temperature of 5 years of Kuala Lumpur weather data (2003-2008), body heat loss graph on Figure 2.1, showed body heat for residents Kuala Lumpur need to evaporate 230Btuh or body heat release through convection and radiation 180Btuh in order to prevent heat stroke.

2.1.2 Evaluation of Thermal comfort

a. The heat-balance approach

The current international thermal comfort standard used by ASHRAE is based on experiments in climate chambers, many of which were completed in the 1960s. *"This approach combines the theory of heat transfer with the physiology of thermoregulation to determine a range of comfort temperatures which occupants of buildings will find comfortable."* (Jones, 1968, pp. 23) The range is determined by a 'PMV' (predicted mean vote), derived from studies of individuals in tightly controlled conditions.

b. The adaptive approach

This approach was suggested by Humphreys, (1992), de Dear (1998) and Brager (1998) which is based on field surveys of thermal comfort and demonstrates that people are more tolerant of temperature changes than laboratory studies: they consciously and unconsciously act to influence the- heat balance inside the body (behavioural thermoregulation). These actions may change metabolic heat production, the rate of heat loss from the body or the thermal environment (windows, doors blinds, fans, thermostat adjustment). This theory was tested by PMV and PPD using BABUC and was explained further in chapter 5.

c. The comfort zones

"The comfort zones are usually expressed graphically as an overlay on the psychometric chart diagram which shows the relationship between temperature and humidity." (Olgyay, 1953, pp. 88) Only a few comfort charts attempt to express the additional major comfort variables of mean radiant temperature (MRT) and air motion.

Givoni, (1976) has stated that "There is no one temperature and humidity condition at which everyone is comfortable. People are comfortable at a range of temperatures and humidity." Research conducted over many years on large numbers of people by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE 55-2004) concluded there is a range of combined temperature and humidity that provides comfort to most people. This Comfort Zone Chart shows 'Indoor Air Temperature' on the vertical axis, "Relative Humidity" on the horizontal axis, and a shaded area known as the 'Comfort Zone'.

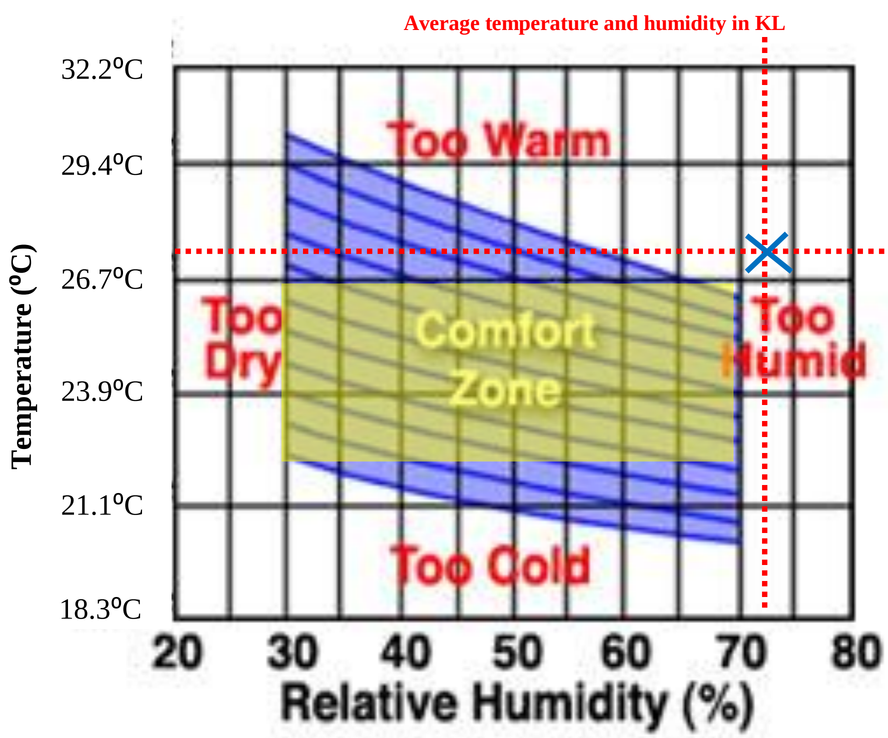

Figure 2.2: Thermal comfort for human
(Source: Givoni, 1976)

Givoni, (1976) also said that "Most people are comfortable at higher temperatures if there is a lower humidity." As the temperature drops, higher humidity levels are still within the comfort zone. Based on Figure 2.2 shows the average temperature and humidity in Kuala Lumpur falls under too humid and too warm. Wong (2003), De dear (1991) and Busch (1990) stated that thermal comfort level that has been determined by respondents in Malaysia which can be defined as Malaysia Standard is in the range of 26°C- 30.7°C and humidity between 30-70% which is within the comfort zone that has determined by ASHRAE standard 55-2004.

2.2 Ventilation as building requirements

Good ventilation provides adequate amounts of outdoor air and circulates air in the building to dilute and remove odours and contaminants and keep air temperature consistent within the building. The Occupational Health and Safety Regulation list a number of requirements for building ventilation systems where building design must meet these requirements to protect the health and comfort of the occupants as shown in Table 2.1. (Bansal, 1994, pg 12.1)

An adequate supply of outdoor air must be provided to the workplace or residential area in accordance with Table 2.1 of *ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality*. The amount of outdoor air required varies according to the type of building or facility, activities, and occupant density. As a general guideline, many workspaces or residences will require between 0.42 and 0.57 cubic meter per minute (cfm) of outdoor air per person and 15 air changes per hour. (Bansal, 1993, pg. 11.9)

There is an exception to this requirement. If a building ventilation system was installed before 1989, an adequate supply of outdoor air must be provided in accordance with the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standard in place at the time the ventilation system was designed, not the 1989 standard. This theory was used as a reference in Malaysia (Zakaria, 2006).

Outdoor air must be effectively distributed throughout the workplace or residences. The ventilation system must be balanced to ensure that each space within the building receives an adequate amount of outdoor air and to accommodate the normal occupancy of each space. The minimum (intake) volume setting should equal the larger of the following:

- 30% of the peak supply volume
- 0.002 m3/s per m^2(0.4 cfm/ft^2) of conditioned area (http://www.state.nj.us)

Data above was applicable in Malaysia as a reference.

Table 2.1: Summary of standard ventilation requirements of ASHRAE and UBBL (Source : Ubin, 2008, Chand and Krishak, 1986)

Item	ASHRAE	UBBL / local requirement
Ventilation requirement	0.002 m3/s per m^2(0.4 cfm/ft^2) of conditioned area	10% of the total floor area (to be explained further in chap 2.2.4)
Day lighting	300 lux	
Temperature	20-27°C	24°C
Air speed	0.8m/s	n/a

2.2.1 Ventilation openings

In principle, ventilation systems must not be obstructed by any material or equipment placed in front of the ventilation air intakes or discharge points. Obstructions can significantly change airflow patterns of air quantities in a space and prevent proper control of conditions in the space. Outdoor air intakes must be located properly so they do not draw in air that is more polluted than the normal air in that locality. In general, outdoor air intakes should not be located at loading bays, parking garages, or cooling tower enclosures (Aboulnaga, 1998, pg 12.4).

To ensure adequate ventilation, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) mentioned that the living area should be ventilated at a rate of 0.35 air changes per hour or 0.42 cubic meter per minute (15 cfm) per person. ASHRAE recommends intermittent or continuously. Ventilation rates for bathrooms and kitchens as alternatives to operable windows are 1.42 cubic meter per minute (50cfm) or 0.57 cubic meter per minute (20 cfm) for bathrooms and 2.83 cubic meter per minute (100cfm) or 0.71 cubic meter per minute (25 cfm) for kitchens, respectively (Aynsley, 1995).

2.2.2 Air exchange

Ventilation systems that discharge air from residential area must be designed to minimize the likelihood of exposing to any residents around the house, including an adjacent house, to:

- An air contaminant in a concentration that exceeds 10% of its applicable exposure limit or an acceptable ambient air quality standard, whichever is greater.
- An objectionable odour, where practicable (Bevirt, 1996, pg 12.5).

2.2.3 Effect of Air Speed on Comfort

The ASHRAE Guide (1985) specifies an upper limit of 0.8 m/s (160 ft/min) for indoor airspeed, presumably to prevent papers flying around and feeling cold drafts from the cooled air flowing out of the ventilation system’s diffusers (Fanger 1972, Stein 2006).

2.2.4 Natural lighting and ventilation (Building By laws 1984)

With the aspect of lighting and ventilation, the Malaysian Building by Laws 1984, Section 39 stated:

(1) "Every room designed, adapted or used for residential, business or other purposes except hospitals and schools shall be provided with natural lighting and natural ventilation by means of one or more windows having a total area of not less than 10% of the clear floor area of such room and shall have openings capable of allowing a free uninterrupted passage of air of not less than 5% of such floor area.

(4) Every water closet, latrine, urinal or bathroom shall be provided with natural lighting and natural ventilation by means of one or more openings having a total area of not less than 0.2 square metre per water-closet, urinal larine or bathroom and such openings shall be capable of allowing a free uninterrupted passage of air. (Ubin, 2008)

Ventilation and lighting requirement stated in UBBL is based on window to floor ratio, which is 10% for habitable area and 5% for wash room. However, if a room having a small frontage and a deep plan, the 10% ventilation and lighting of window to floor ratio will be insufficient. Thus, window to wall ratio is proposed to used in justified the window performance for case studies in this research."

2.3 Microclimate impact on Building envelope

Climate is the average of the atmospheric conditions over an extended period of time over a large region and Bahadori, (1978, pp.54) has defined that-

> *"Temperature, solar radiation, humidity and wind are the principal parameters that define the local climate. Small scale patterns of climate, resulting from the influence of topography, soil structure, and ground and urban forms are known as Microclimates."*

The thermal balance in the urban environment differs substantially from that of rural areas. Added thermal gains as high anthropogenic heat released by cars and combustion systems, higher amounts of stored solar radiation, and blockage of the emitted infrared radiation by urban canyons are present in urban areas. Subsequently, the global thermal balance becomes more positive and this contributes to the warming of the environment. This scenario occurred at JKR 989 which is one of the case studies for this research. It is located at the city centre surrounded by high rise buildings such as hotel, apartments and office towers which to be further discussed in Chapter 5.

2.3.1 Urban heat Island

Understanding the site microclimate conditions is crucial when designing with passive cooling. This equipped designers with the knowledge of wind flow, air velocity and etc. Conventionally, the microclimate of buildings has been largely ignored as an opportunity for advanced passive and active strategies.

"Many cities are dominated by hard and reflective surfaces, which create heat island effects, elevating local temperatures and creating a greater heat load for the air conditioning systems of buildings." (Givoni, 1994, pp. 101)

"This phenomenon, known as 'heat island', which has an adverse impact on the energy consumption of buildings for cooling. Also, wind speed between buildings, is seriously decreased compared to the undisturbed wind speed. This phenomenon, known as 'canyon effect', is mainly due to the specific *roughness of a city and channelling effects through canyons."* (Balcomb, 1992, pp. 24)

According to Oke et al, (1991) this phenomenon is mainly influenced by the following factors:

- complex radioactive exchange between buildings and the screening of the skyline
- large thermal mass of the buildings that stores sensible heat
- the anthropogenic heat released from transport, air conditioning, industry, other combustion processes and animal metabolism
- the urban greenhouse
- the canyon radiate geometry that decreases the effective albedo of cities
- the reduction of evaporating surfaces in the urban areas
- the reduced turbulent transfer of heat from within streets

These above statements presented heat island as a consequence of heat balance, air temperatures in densely built urban areas when they are higher than the temperatures of the surrounding rural country. This impact of heat island demands the increase of energy used for cooling the buildings. At the same time, Santamouris (2001) found that, *"Besides the temperature increase, cities affect many other climatologically parameters."* Wind speed and direction in cities is seriously decreased compared to the undisturbed wind speed. This is mainly due to the specific roughness which is the lack of green area in a city and channelling effects through canyons. "*Studies on the Kuala Lumpur area concluded that during the period between 1985 till 2000, the cooling load of existing buildings increased up to 50% on average because of the heat island phenomenon*" (Hui, 2000, pp. 6).

Other factors contributing to the increase of cooling load is when a building is overheated. In order to examine the possible causes of overheating, building elements or components which contribute to the impact on heat transfer into the building are investigated. The result of the investigation will be determined by the exterior and interior or indoor environmental factors. The exterior environmental factors related to: solar radiation, outdoor air temperature, other external temperatures of sky, ground and surrounding surfaces, wind conditions, outdoor air humidity, and outdoor concentration of pollutants. The indoor condition will be influenced by heat gains derived from lighting, occupants and the equipment, sources of humidity and pollutants and sensible and latent heat.

2.3.2 Internal Heat Gains

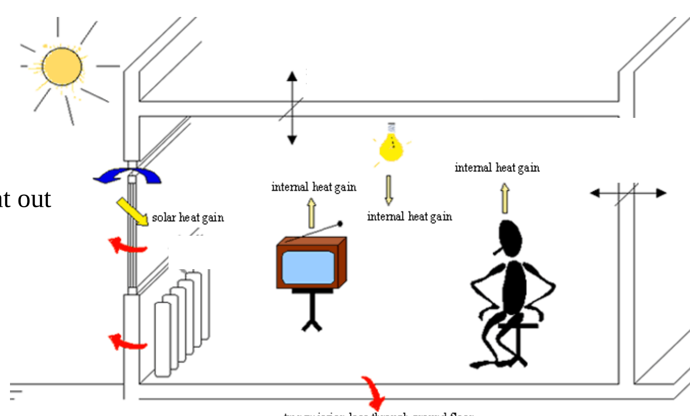

Figure 2.3: Sources of heat that enter into the building
(Source*:* Auliciems, 1997, Hasegawa, 1983)

Figure 2.3 shows factors that influence indoor heat gain, which include: direct solar radiation through windows and skylights; air leakage; heat transfer and infiltration, of outdoor temperature, through the materials and elements of the structure; and the internal heat generated by appliances, equipment and inhabitants.

2.3.3 The role of building envelope in controlling heat gain inside the building

a. Building Fabric

Building fabric is a critical component of the building, since it both protects the building occupants and plays a major role in regulating the indoor environment. *"Consisting of the building's roof, floor slabs, walls, windows, and doors, the fabric controls the flow of energy between the interior and exterior of the building."* (Sharma, 1994, pp.40) An optimal design of the building fabric may provide significant reductions in heating and cooling loads- which in turn can allow downsizing of mechanical equipment.

b. Roofs

"About a third of the unwanted heat that builds up in your home comes in through the roof. This is hard to control with traditional roofing materials." (Bennett, 2000, pp.90) For example, unlike most light coloured surfaces, even white asphalt and fiberglass shingles absorb 70% of the solar radiation as stated in study done by Bennett (2000).

c. Walls

Wall colour is not as important as roof colour, but it does affect heat gain. White exterior walls absorb less heat than dark walls. *"Bright walls increase the longevity of siding, particularly on the east, west and south sides of the house."* (Rao, 1972, pp.20)

d. Windows as part of the wall component plays a big role on heat transfer

Window compared to other building elements contribute majority of heat gain into building, Ernest, (1991) has support this argument and said that *"Roughly 40% of the unwanted heat that builds up in homes is through windows."* Therefore in order to achieve indoor comfort, window design needs to take into serious consideration.

Figure 2.4: sample components of windows (Source: www.bca.gov.sg)

The effectiveness of windows in controlling air movement depends not only on the opening size but also on the type of window (only operable windows are considered as airflow control devices) which shown in Figure 2.4. The wide variety of wall window styles, regardless of their plane of placement or position on the building envelope, can be classified as one or a combination of three primary window types:

Simple opening, defined as *"any window that opens by sliding in a single plane and including single hung, double hung and horizontal sliding windows"* (Chand, 1986)

- Vertical vane opening, defined as *"any window that opens by pivoting on a vertical axis such as the side hinged casement (single sash or double sash), folding casement, and vertical pivot window"* (Chand, 1986)
- Horizontal vane opening, defined as *"any window that opens by pivoting on a horizontal axis and including the projected sash, awning, basement, hopper, horizontal-pivot, and jalousie windows"* (Chand, 1986)

Table 2.2: Type of windows (Source: www.bca.gov.sg)

Type of window	Description
Fixed glass 	• Has a fixed glazed sash • Designed mainly for providing view, admitting light and for aesthetic purposed
Casement 	• Sash opens on hinges, pivots or friction stays • Allows airflow through almost the entire area of the window opening • Designed mainly for providing view, admitting light, allowing for natural ventilation and for aesthetic purposes
Top hung (awning) 	• Similar to casement window, except that the sash is connected by friction stays at the top of the window frame • Designed mainly for providing view, admitting light and allowing for natural ventilation

Bottom hung (hopper) 	• Similar to top hung window, except that the sash is connected by friction stays at the bottom of the window frame • Designed mainly for providing view, admitting light and allowing for natural ventilation
Sliding 	• Consists of two or more sashes, which slide horizontally or vertically along tracks • Do not require space for swinging of sashes, hence, useful at locations next to passage ways • Except for specially designed window, not possible to achieve ventilation through the entire window opening • Designed mainly for providing view, admitting light, allowing natural ventilation and for aesthetic purposes
Louvered 	• Comprises horizontal glass panes, which are either fixed at an angle, or adjustable to control the amount of light and ventilation through the window • Designed mainly for admitting light and allowing for natural ventilation
Bay window 	• Generally comprises a series of windows assembled in a polygonal arrangement • Projects outward from the external façade of a building • Designed mainly for providing view, admitting light and allowing for natural ventilation. can be a pleasant element to a building façade

Refer to studies done by Chand (1986), all the above types of windows shown in Table 2.2 are usually installed on walls but all or some of them can be installed on roof monitors as well. Roof monitors include dormers, clerestories, skylights, belvederes and cupolas. Dormers and clerestories have openings in a vertical plane; skylights have openings on a horizontal or tilted plane; belvederes and cupolas can have windows in both vertical and non-vertical planes.

A wide variety of airflow patterns is generated by the various types of windows in relation to their operational condition. This is defined by: the effective open area, i.e. the open area as projected perpendicularly onto the flow; the tilt angle between flow direction and displacement plane of the sash; the degree of symmetry of the sashes relative to the axis of the window and the flow direction.

i. Size of Windows

Based on studies done by Hui (2000), functions of windows are to provide daylight, visual contact with the outdoors, and ventilation. Openings in a hot humid climate play a major role in determining the thermal comfort of the occupants as their location and size determine the ventilation conditions of the building. It is desirable to have independent cross ventilation to every individual room in the building. In practice it is difficult in many cases to have independent cross ventilation of every individual room in the building, especially in large apartment buildings or even in townhouse rows. In such cases, it is important to make sure that air can flow in and out of every room, passing through a series of rooms or a hall in the building on its way to the outlet openings.

When the wind direction is at a very small angle to the wall – it is still possible to create effective cross ventilation. To do so, there must be "*at least two windows in the windward wall, and each one must have a single 'wing wall' – a single vertical projection on one side of the window"* (CIBSE, 2004, Bonine, 1980).

ii. Airflow Patterns through Windows On Walls

Simple openings do not generally affect the pattern or velocity of airflow except near the window as the airstream squeezes through the opening. A double-hung window allows selection of the height of the airflow, while a horizontal sliding window designates the placement of the airstream within the interior space as shown in Figure 2.5.

Single hung window   Double hung window   Horizontal sliding window

Figure 2.5: Sample opening windows
(Source: Salmon, 1999, pp. 24)

Vertical – vane openings exert a wide variety of influences on both the pattern and velocity of the airflow with a particular effect on the horizontal airflow pattern. *"The most common window of this type, the side – hinged casement window, has a great versatility with regard to airflow control"* (Elias, 1994, Kannan, 1991, Koenigsberger, 1975.)

According to Hui (2000), *"The side – hinged casement window can be installed as a one – sash or two – sash unit; the sashes can be inswinging, i.e. opening towards the inside of* *the space, or outswinging, i.e. opening towards the outside of the space."* The airflow patterns depend on the type of unit, the type of opening and the operational position of the sashes.

Horizontal – vane openings influence the velocity and pattern of air movement mainly on the vertical direction, although their versatility is limited. Refer to Hui (2000), *"projected sash, basement and horizontal pivot windows direct the airflow upward; hopper windows and horizontal pivot windows installed in reverse direct the airflow downward."*

2.3.4 Window design factors

a. Window- wall ratio

The window wall ratio is the percentage resulting from dividing the total glazed area of the building by the total wall area. Too high a WWR can result in too much light in the building, creating glare on computer screens and fading upholstery, artwork, printed materials and carpets. It can also contribute to the building being too hot from all the sunlight and heat coming in. The ASHRAE 90. 1-1999 requires:

Orientation provides impact on the performance of WWR.

South side: maximize the WWR as to allow sufficient daylight in but it is also less heat gain from south windows than there is from east and west windows because of the sun's angle.

North side: maximize WWR as to allow daylight

East and West sides: the east and west windows can interfere with the activities inside by introducing too much direct light into a space, which can cause glare in addition to contributing to heat gain issues. (Nieuwolt, 1984, pg. 123)

b. U Value (Thermal)

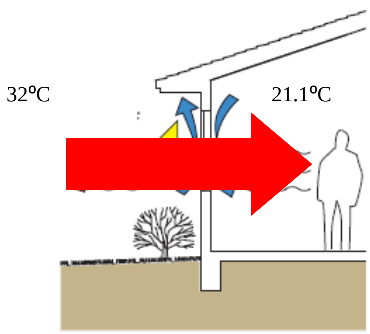

Figure 2.6: U value concept and formula
(Source: Lee, 1979)

$$U = \frac{1}{R_o + R_i + R_c + R_{\beta 1} + R_{\beta 2}}$$

R_o - thermal resistance outside surface
R_i - thermal resistance internal surface
Rc - thermal resistance air cavity
$R_{\beta 1}$ - thermal resistance building components
$R_{\beta 2}$ - thermal resistance building components

The U value as shown in Figure 2.6 is a measure of how well heat is transferred through an assembly such as window. The lower the U value, the less heat is transferred. Old, poorly insulated and poorly fitted single pane window can have a U value of 1.2W/m²K or more. A super insulated wall assembly could have low U value of around 0.02 W/m²K. The best insulated, most expensive triple glazed windows can have a U value of 0.09 W/m²K and many commonly available and affordable double glazed windows have a U value of 0.35 W/m²K. The perfect value for low U value window with the expected energy savings and life cycle costs is 0.27 W/m²K (Hyde, 1998, Watson, 1983).

c. Solar Heat Gain Coefficient (SHGC)

Solar Heat Gain Coefficient is a measure – unit to show how much of the sun's heat energy passes through a window assembly. It is measured on a theoretical scale from 0 to 1, with 0 meaning that none of the heat energy that hits the window passes through (like a theoretical solid wall) and 1 meaning that all of it does (like a hole in the wall). The perfect SHGC for residential is 0.30 as to minimize heat gain. (Bennett, 1978, pg 121)

> *"Solar Heat Gain Coefficients (SHGC) must be less than 0.40 (0.61 for north facing), equivalent to Shading Coefficient of 0.46 and 0.70. In terms of window wall ratio (WWR): 0.24, falling into the preferred range to achieve both thermal and day lighting performance."* (ASHRAE, 1985)

Solar heat gain coefficient depend on glazing performance especially tinted glass or double glazing glass. As all the windows in case study are installed with 5mm thick single glazing clear glass, thus, not much heat can be reduced even though windows were closed.

d. Visible Light Transmittance (VLT)

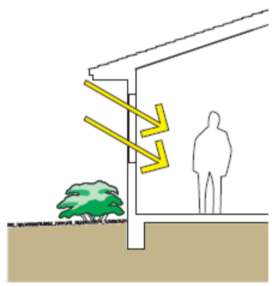

Figure 2.7: Visible light transmittance
(Source: Lee, 1979)

Figure 2.7 shows visible light transmittance which is a measurement that will show how much light passes through a window. It is measured on a scale of 0 to 1, with zero meaning that none of the visible light is transmitted, (such as solid wall) and 1 mean that all of it is, (such as a hole in the wall). *"Typical window values range from 0.3 to 0.8, since glass alone will reduce VLT. VLT of 0.50 for most of our windows to maximize the day lighting opportunities and minimize glare."* (Cowan, 1980, Hyde, 2000)

e. Light to Solar Gain (LSG)

It is a ratio comparing a window's light transmittal efficiency in relation to its solar gain. The higher the number, the better the window is at blocking solar gain while allowing visible light to pass through. For typical values, Poor<1.00, Excellent >1.55. VT/SHGC=LSG. (Hobbs, 1980, pg. 20). Table 2.3 shows summary of ventilation and day lighting requirement.

Table 2.3: window design requirement

Ventilation / heat gain	Value	Remarks
Ventilation opening	0.42cubic meter per minute (15cfm) (living room) 1.42cubic meter per minute (50cfm) or 0.57cubic meter per minute (20cfm) (bath) 2.83 cubic per minute (100cfm) or 0.71 cubic per minute (25cfm) (kitchen)	
U value	0.27	expected energy saving & life cycle cost
Window to wall ratio	0.24	achieve both thermal and day lighting performance
Solar heat gain coefficient	0.30	minimum heat gain
Visible light transmittance / visible transmittance	0.5	maximum light, minimum glare
Light to solar gain	>1.55	block solar gain while allow visible light pass through

2.4 Energy Consumption in Buildings

Energy is defined as the ability to do work. In this sense, examples of work include moving something, lifting something, warming something, or lighting something. The following is an example of the transformation of different types of energy into heat and power. "*Oil burns to make heat, heat boils water, water turns to steam, steam pressure turns a turbine, turbine turns an electric generator, generator produces electricity, electricity powers light bulbs, light bulbs give off light and head*" (Kleunne, 2003, pp. 41).

It is difficult to imagine spending an entire day without using energy. In a home where electricity supplies all of the energy requirements, the average energy consumption is shown in Figure 2.8,

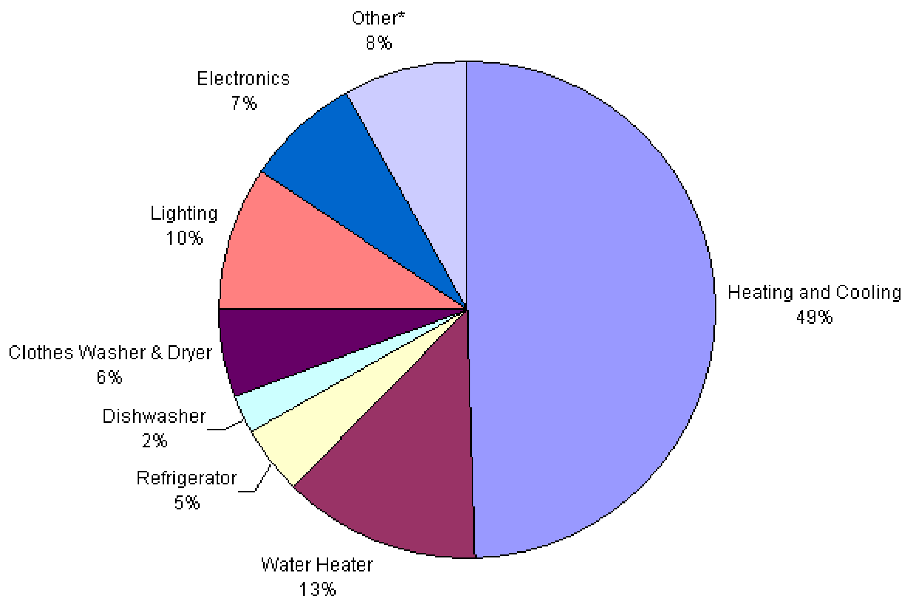

Figure 2.8: Energy usage at home
(Source: Julaida, 2004, pp.59)

Air conditioner	=	49%
Water heater	=	13%
Lighting and small appliances	=	10%
Electronics	=	7%
Clothes dryer	=	6%
Refrigerator	=	5%
Ovens and stoves	=	4%
Other	=	8%

Electricity is generated from both renewable and non-renewable energy sources. These sources are defined below. (Lee, 1979, Yunus, 1986, Chalfoun, 1999)

2.4.1 Renewable energy sources:

These sources are constantly renewed or restored and include wind (wind power), water (hydropower), sun (solar), vegetation (biomass), and internal heat of the earth (geothermal).

2.4.2 Non-renewable energy sources:

"About 80% of electricity in Malaysia is generated from non-renewable sources." (Kannan, 1991) Most electricity in Malaysia is generated by burning non-renewable fossil fuels and there is a limited amount of these energy sources.

2.4.3 Energy Crisis

"Buildings use almost 40% of the world's energy, 16% of the fresh water and 25% of the forest timber (Al-Hemaidi, 2001), while is responsible for almost 70% of emitted sulphur oxides and 50% of the carbon dioxide." (Cole, 1997, pp. 122) Energy consumption of the building sector is high. *"Although figures differ from country to country, buildings are responsible for about 30-40% of the total energy demand."* (Esmawee, 1993, pp.9). Application of intensive energy conservation measures has stabilized energy consumption for heating in developed countries. However, energy needs for cooling increases in a dramatic way. The increase of family income in developed countries has made the use of air conditioning systems highly popular. *"In Malaysia, the final energy demand in 2000 is almost a fivefold increase from year 1980. Furthermore, the Malaysia Energy Centre*

estimates that carbon dioxide emissions per capita from the energy from the energy sector increased 45% from 1994 to 2005." (Zakaria, 2006)

The impact of air conditioner usage on electricity demand is an important problem as peak electricity load increases continuously, forcing utilities to build additional plants. In parallel, serious environmental problems are associated with the use of air conditioning. With the increase of living standard, the demand of air condition is getting higher.

2.5 The disadvantages of air conditioning systems

The air conditioning market is expanding continuously.

> *"Most of the units are installed in North America, where the sales are not expected to increase further. In Europe, an increase of 22.3% between 2002 and 2006, while the corresponding increases are expected to be 39.2% for the remainder of Asia, 23.2% for Oceania, 13.6% for Africa, 13.3% for South America and 10.5% for Middle East."* (Jain, 2006, pp. 212)

Increased number of air conditioned being sold means more and more people are installing them in order to cool down the interior. Designing climate responsive buildings is not taken into account by many designers as they tend to take the easy way out.

There are different problems associated with the use of air conditioning. Apart from the serious increase of the absolute energy consumption of buildings, other important impacts include:

1. The increase of the peak electricity load;

High peak electricity loads oblige utilities to build additional plants in order to satisfy the demand, but as these plants are used for short periods, the average cost of electricity increases considerably. *"ASEAN countries face a very steep increase of their peak electricity load mainly because of the very rapid penetration of air conditioning."* (Krishan, 2000, pp. 20) For example, "*Malaysia faced significant electricity problems during 2003 because of the high electricity demand of air conditioners. It is expected that the future increase of the peak load may necessitate doubling installed power by 2020*" (Zakaria, 2006)

2. Environmental problems associated with the ozone depletion and global warming;

"For many years, Malaysia has been blessed with oil and natural gas." (Yunus, 1986) As energy costs continue to rise and fossil fuels deplete, maintaining a balanced socio-economic fabric is becoming an expensive proposition for the Government. As a consequence, the electricity demand will continue to increase and the supply will start to fall below demand, thus dramatically increasing the electricity prices. The main environmental problems of air conditioning are associated with:

- Emissions from refrigerants used in air conditioning which adversely impact ozone levels and global climate. Refrigeration and air conditioning related emissions represent almost 64% of all CFC's produced (Bennett, 1978)
- Cooling systems' energy consumption contributes to carbon dioxide emissions

3. Indoor air quality problems.

Air conditioning systems may be an important source of indoor contamination. Cooling coils and condensate trays can become contaminated with organic dust. This may lead to microbial growth. The organic dust may also cause mold and fungal growth in fans and fan housings. Inefficient and dirty filters may also lead to unfiltered air in the building.

> *"Contaminated emissions from cooling towers may cause spread of diseases like Legionelea from poorly maintained systems. Humidity condensation and the growth of mould affected the health of the occupants and impacted the productivity and performance of the occupants of buildings."* (Khedari, 2000, pp. 3)

Air conditioning units are considered as energy guzzlers. They consume the highest percentage of energy usage at home compared to other equipments. As almost every family in Malaysia consumes air conditioning, there is serious energy crisis and environmental problems associated. In order to conserve energy, there is option of introducing natural ventilation.

2.6 Natural Ventilation

Natural ventilation is a back to basic approach using Mother Nature as the principle driving force. It offers low energy cooling strategy which can provide year round comfort, with flexible user control, but with a low capital and maintenance cost if there is sufficient wind. Figure 2.9 shows natural ventilation strategies are founded on two basic operational strategies essentially comprising of wind driven (cross ventilation) or buoyancy (stack effect) system.

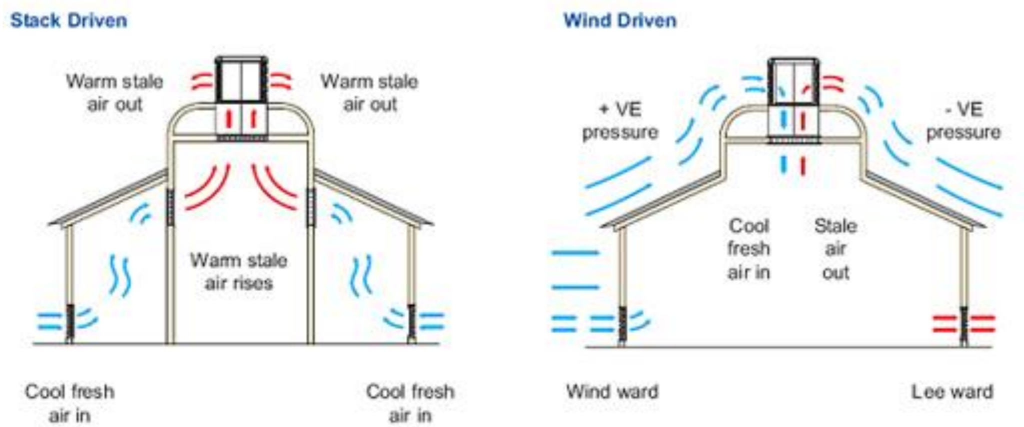

Figure 2.9: Natural ventilation strategies
(Source: Givoni, 1976, pp.305)

Cross ventilation depends on two continuously changing factors: wind availability and wind direction. In wind driven systems (cross ventilation) the air on the wind ward side of the building creates a positive pressure with corresponding negative pressure generated on the leeward side as shown in Figure 2.10. Using this effect, air can be easily drawn through the building. Although wind driven systems can be effective, building design, orientation and location factors are important for a successful result.

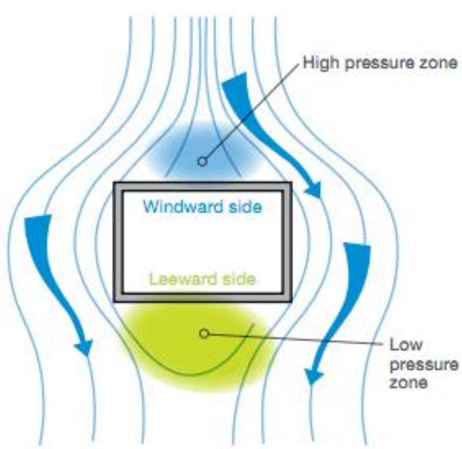

Figure 2.10: Pressure effect from wind
(Source: Wise, 1965, Mclntyre, 1978, Samirah, 1999)

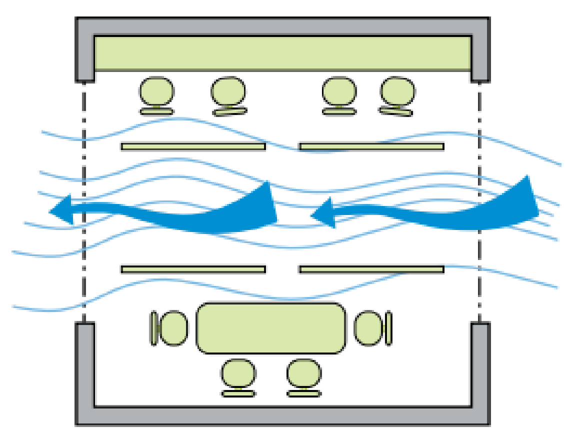

Figure 2.11: Partition designed to minimise resistance for effective cross ventilation
(Source: Wise, 1965, Mclntyre, 1978, Samirah, 1999)

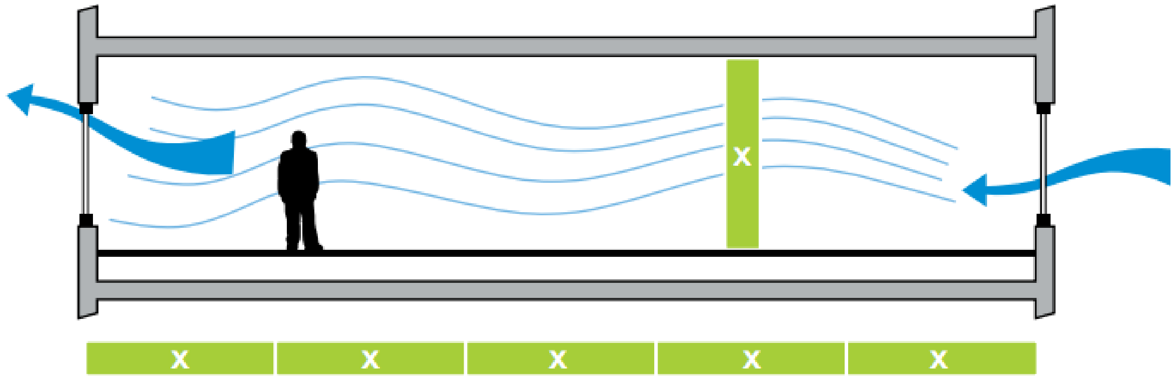

Figure 2.12: Cross ventilation rule of thumb – effective for up to five times the ceiling height
(Source: Wise, 1965, Mclntyre, 1978, Samirah, 1999)

The use of cross ventilation will have a strong influence on the building aesthetics and site planning. To maximize the effectiveness of openings, narrow buildings with open plans and well placed openings work best. Building elements like fins, wing walls, parapets and balconies may be designed to enhance wind speeds and should be an integral part of cross ventilation design. Below are some considerations that should be made when designing for cross ventilation:

- *Cross ventilation will work well if the room is up to 5 times the width of the ceiling height as shown in Figure 2.12*
- *If cross ventilation is not possible placing window on adjacent walls, at 90 digress to each other, will work but limit room size to 4.5m x 4.5m*
- *Partitions should not be higher than 1200mm, but this will depend on opening sizes*
- *Partitions should not obstruct air path as shown in Figure 2.6(c)*

Place equipments which generated heat on the east or west facades as these are the areas of highest heat load from the sun with least benefit from windows (Source: Wise, 1965, Mclntyre, 1978, Samirah, 1999)

Buoyancy or stack effect shown in Figure 2.13 relies on vertical stack or shaft in the building to allow warmer air to migrate and rise through the building to high level outlets whilst drawing fresh cool air in from low level. Refer to studies done by Afonso (2000), *"stack ventilation does not rely on the wind. Therefore it offers greater reliability as well as more flexibility on the placement and location of the air intakes. Stack ventilation works best in spaces with high ceilings and where cross ventilation is not feasible."*

Solar chimneys are a method of enhancing stack ventilation. Additional height and well designed air passages increase the air pressure differential. *"Chimneys should be constructed to capture solar radiation to increase the heat of the air at the top and increase the difference in temperature between incoming and out flowing air. The increase in natural convection that occurs from these measures enhances the draw of air through the building*" (Bansal, 1993).

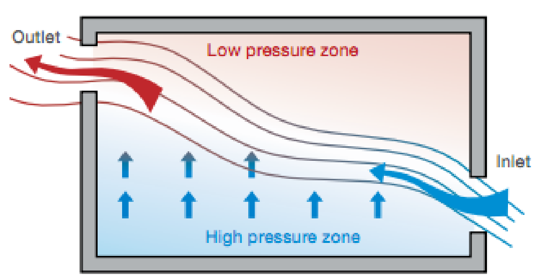

Figure 2.13: Pressure effect from stack ventilation
(Source: Afonso, 2000, Sobin, 1983)

Wind and temperature difference are the two separate forces which drive natural ventilation. Natural ventilation helps us to cool down by sweating. In rural and seaside locations, there will usually be wind to drive ventilation. But offices in towns and cities may often have to rely on the much smaller forces due to the stack effect.

Proper design of energy-conscious buildings requires a balance between two things:

1. The thermal performance of the building envelope and the appropriate selection of techniques for heating, cooling and day lighting
2. An acceptable quality of the indoor climate in terms of thermal comfort, ventilation effectiveness or indoor air quality (Salleh, 1989, pp. 90)

The advantages of natural ventilation are able to provide the answer to many complaints concerning the use of mechanical ventilation, which according to Salleh (1989) appears to be noisy, create health problems, required routine maintenance and to consume energy as well. In contrast, natural ventilation is preferable, as it does not consume any energy, and it can be easily integrated into buildings designs and it provides a healthier and more comfortable environment if integrated correctly.

Natural ventilation is very attractive for designers or architects if it offers robust solutions and capable in providing an acceptable indoor air quality and meeting comfort needs throughout the full range of climate conditions. Natural ventilation has been introduced in many types of buildings in hot and humid countries, especially as part of Malay traditional house architecture, and later on applied on each building built during the British Colonial, included schools, small or medium-sized offices, recreation buildings and public buildings.

The disadvantages behaviour of natural ventilation are affected by the influence of uncontrollable environmental factors of the micro climate.

> *"The physical phenomena has to take into account when correspond to simple concepts like thermal mass and they are yet easy to handle because of many uncertainties, for example the randomness of indoor airflow*

patterns and the difficulty of determining the surface heat transfer between the air and the walls." (Hokoi, 1983, pp.98)

Furthermore, in many urban environments, outdoor environmental conditions may not be acceptable because of air and noise pollution. In these conditions, natural ventilation can be unsuitable or will need a special design in order to avoid a direct link between indoor and outdoor environments.

2.6.1 Cooling process of Natural Ventilation

Use of natural ventilation for cooling process during the daytime has three objectives:

1. Cooling of the indoor air as long as outdoor temperatures are lower than the indoor temperatures
2. Cooling of the structure of the building
3. A direct cooling effect over the human body (through convection and evaporation)

2.6.2 Passive cooling concept

In order to achieve thermal comfort in a building, there are varieties of solutions such as application of hybrid system + passive cooling, utilize suitable building material. Passive cooling is a traditional method that exploits natural sources to cool the building. It can be achieved by solar and heat protection techniques (by modifying the physical condition of building), heat modulation techniques (utilized suitable building material) and heat dissipation techniques (hybrid cooling).

a. Solar and Heat Protection Techniques. Protection from solar and heat gains may involve: Landscaping, and the use of outdoor and semi-outdoor spaces, building form, layout and external finishing, solar control and shading of building surfaces, thermal insulation, control of internal gains, etc.

   *This will encourge the research to focus on solar and heat protection techniques as window is an element that can be controlled the heat gain by deciding its orientation, opening dimension, shape of window, types of openings and etc.

b. Heat Modulation Techniques. It is impossible to conduct experiments regarding night ventilation in Kuala Lumpur as it required openings to be opened during night time and closed during daytime. Case studies that have chosen majority either converted into office (which open only during working hour, from 8am – 6pm, such as JKR 989 and JKR 511) or abandoned (which is closed all the time, such as JKR 1331).

c. Heat dissipation techniques. These techniques deal with the potential for disposal of excess heat of the building to an environmental sink of lower temperature.

2.6.3 Convective Cooling Models

"The next step in natural cooling is to take advantage of convective cooling which use the prevailing winds and natural, gravity-induced convection to ventilate a house at the appropriate times of the day." (Lee, 1998, Sullivan, 1972)

> *"Another convective cooling strategy is the drawing of outdoor air through tubes buried in the ground and dumped into the house."* (Hanafiah, 2005 pp. 45)

This means for material that allows easy thermal transfer, these tubes are buried several feet deep to avoid the warmer daytime surface temperatures.

2.6.4 Passive cooling strategies

According to studies done by Givoni (1976) showed that before refrigeration technology first appeared, people kept cool using natural methods: breezes flowing through windows, water evaporating from springs and fountains as well as large amounts of stone and earth absorbing daytime heat. These ideas were developed over thousands of years as integral parts of building design. Today they are called 'passive cooling'.

> *"Natural cooling is an element of passive solar design, and involves blocking heat transfer through shading, insulation, thoughtful landscaping and window placement; removing heat with fans, vents and cross ventilation and reducing the use of heat generating lights and appliances."* (Olgyay, 1963, pp.89)

Refer to Bansal (1994) stated that in dry climates, evaporative cooling systems which distribute moist air to cool a room are a good natural alternative to traditional air conditioners. By employing passive cooling techniques into modern buildings, the size and cost of the equipment for mechanical cooling can be at least reduced.

Passive cooling strategies are shown on this version of the bioclimatic chart as overlapping zones. These passive cooling concepts address getting rid of heat that accumulates in buildings. Based on Figure 2.14, suitable passive cooling strategies for this research is natural ventilation.

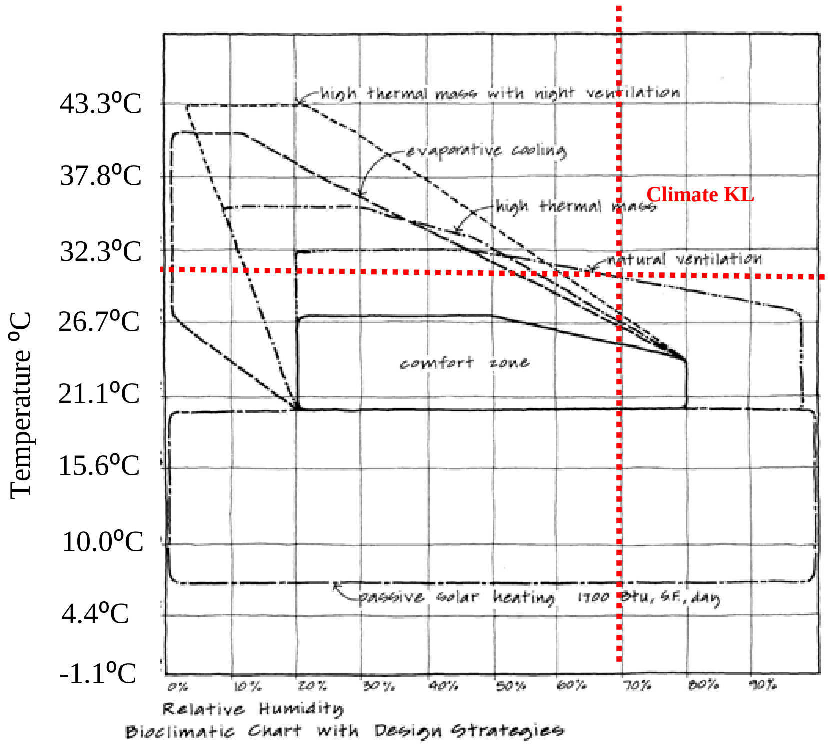

Figure 2.14: Passive cooling strategies
(Source: Olgyay, 1963, pp. 91)

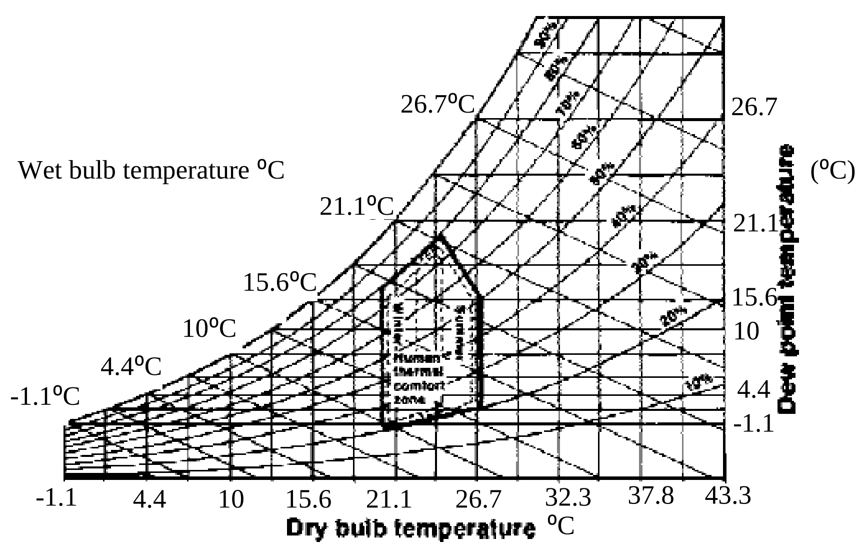

Figure 2.15: Basic comfort zone
(Source: B. Givoni, London, 1976)

Research accomplished by P.O.Fanger (New York, 1970) with large numbers of subjects has shown in Figure 2.15, for instance, that comfort can be maintained at 28°C (82°F) and 70% relative humidity as long as air velocities of 1.52 m/s across the skin are maintained. At lower relative humidity (50% and below) much higher temperature (up to 32°C (90°F) are comfortable at this air velocity. (Givoni, 1976, pp. 14)

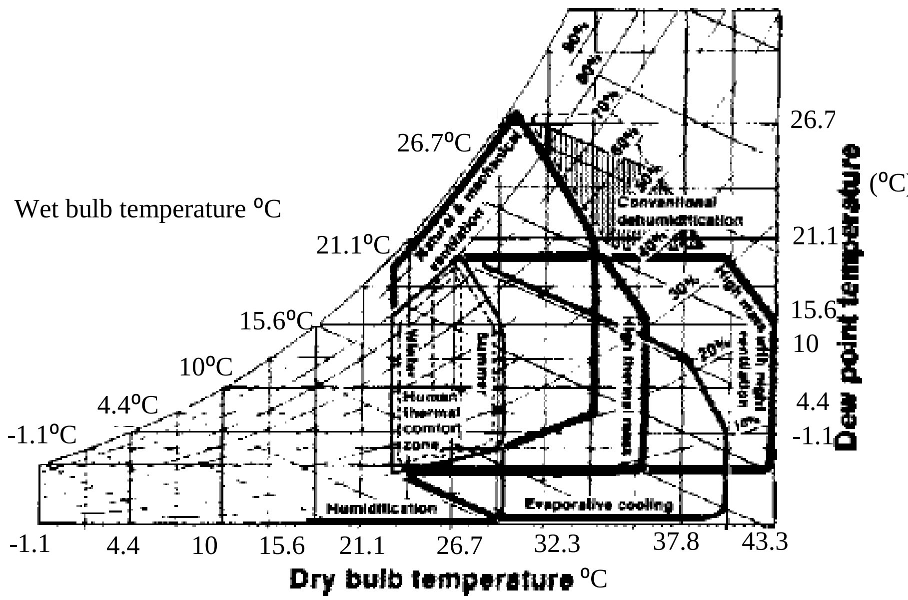

Figure 2.16: Expanded comfort zones
(Source: Givoni, 1976, pp. 20)

An expanded version of the comfort zone has been provided by Givoni. Figure 2.16 showed what can be achieved through effective passive building design. The various zones are based on exterior climate conditions and show building comfort-producing potentials for selected building design techniques.

"The shaded area indicated the additional potential of certain combined techniques. For instance, the wise use of thermal mass and ventilation in this zone can produce

comfortable interior conditions." (Givoni, 1976, pp. 44) However, comfort chart provided by Givoni more suitable to use for hot, dry climate.

"Natural ventilation depends solely on air movement to cool occupants. Window openings on opposite sides of the building enhance cross ventilation driven by breezes." (Sullivan, 1986, pp.76) Since natural breezes can't be scheduled, designers often choose to enhance natural ventilation using tall spaces within buildings called stacks effect as per stated in studies done by Afonso (2000). With openings near the top of the stack, warm air can escape, while cooler air enters the buildings from openings near the ground. Ventilation requires the buildings to be open during the day to allow air flow. *"High thermal mass with night ventilation relies on the daily heat storage of thermal mass combined with night ventilation that cools the mass."* (Fathy, 1973, pp.112) The buildings must be closed during the day and opened at night to flush the heat away.

2.6.5 Passive cooling in traditional architecture

There are several features of traditional architecture suggested by Salmon (1999), Krishan (2000) and Roaf (2004) which led to thermal comfort conditions in buildings as shown in Figure 2.17 such as contextual surroundings and orientation of the building, appropriate climatic responsive form of a building, clustering pattern according to natural shading and thermal insulation, provisions of a courtyard for ventilation and lighting and also controlling the harshness of the tropical sun, limiting the number and size of the openings which not only reduces the heat gain but also the dust entering the building, by constructing the walls of the building of thick adobe bricks so as to increase the time lag, provision of shading devices like screens, Jharokha's eaves projection, verandas, arched recesses, cornices, parapets etc, provision of vertical shafts or wind catchers to cool and circulate the air through buildings, use of vegetation and water bodies, exterior surface painted white or light colour for reflection of heat radiation, provisions of soft surfaces around the building, such as, artificial mounds, grass cover etc.

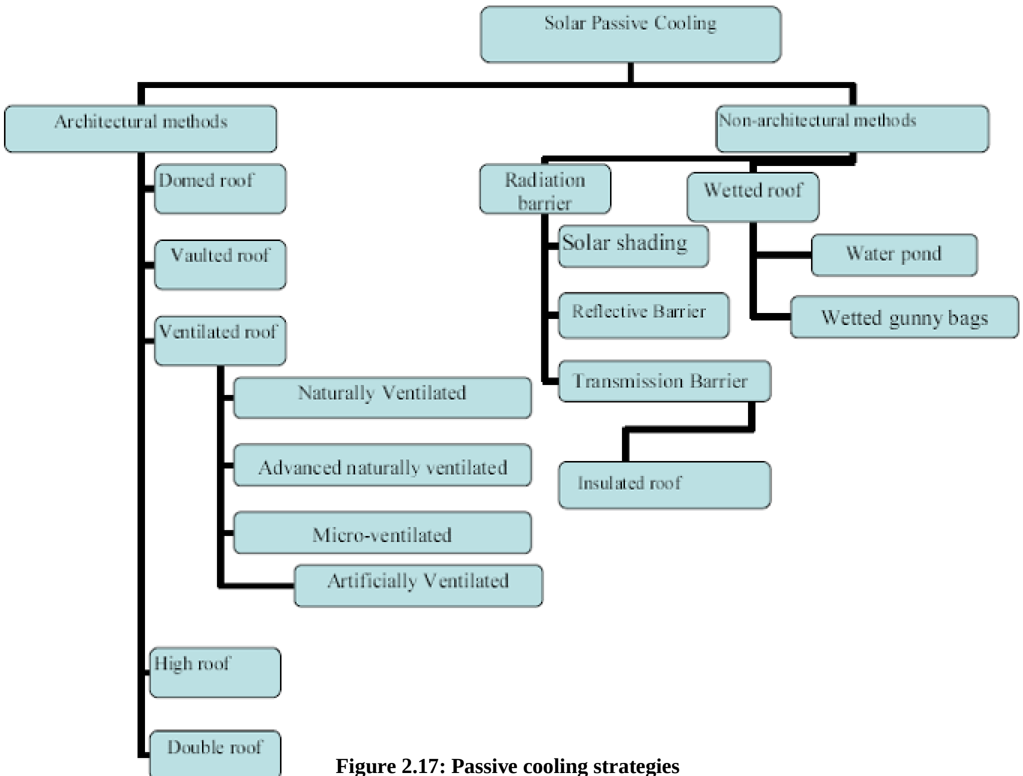

Figure 2.17: Passive cooling strategies
(Source: Roaf, 2004, Bansal, 1994, Chandra, 1986)

Architectural techniques

a. Domed and vaulted roof

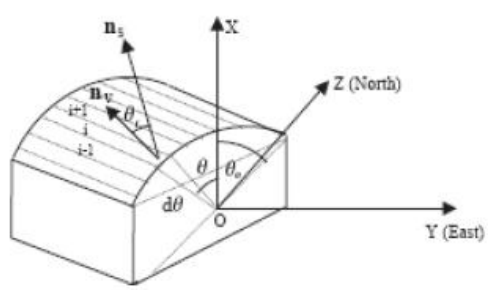

Figure 2.18: Sketch of a house with vaulted roof
(Source: Khedari, 1997, pp. 130)

The advantage of this Figure 2.18 is that curved roofs reflect more radiation than flat roofs due to their enlarged curved surface. The other reason is that in these roofs due to thermal stratification, all hot air within the building with curved roofs gathers in space under the roof, hence creating a significantly comfortable feeling at the floor level. (Khedari, 1997, pp.131)

b. Ventilated roofs

Various types of ventilated roofs systems are naturally ventilated, artificially ventilated and micro ventilated. Figure 2.19 showed ventilated buildings which are structures that have hollow walls and roofs through which a certain amount of air flow is maintained. The air flow is regulated in such a way that minimum heat is transferred to or from the building interior and exterior. (Khedari, 2000, pp.144)

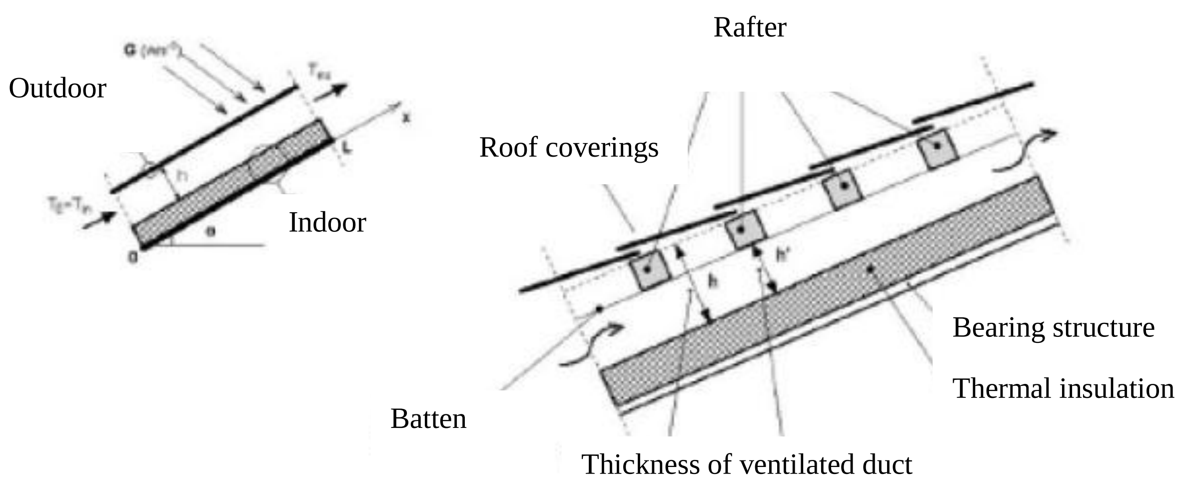

Figure 2.19: Ventilated and micro ventilated roof system for passive cooling
(Source: Aynsley, 1995, pp. 120)

c. Natural Ventilation – Stack effect

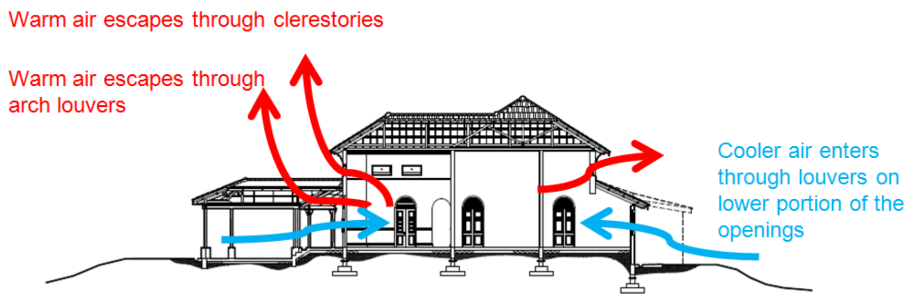

Figure 2.20: Section drawing of JKR 989 showing the ventilation that occurs.
(Source: Lim)

The term advanced natural ventilation is for buildings which utilize the stack effect in which air warmed by internal sources of heat drives the air flow and does not necessarily rely on wind pressure if properly designed and controlled. Figure 2.20 explained how the stack effect works in British Colonial buildings (Afonso, 2000, pp.155). Malay house also have jack roof which encourage stack effect and clay tiles roof of Malay house are tiled in a way that assist internal ventilation.

d. High roof

Figure 2.21: Taj Mahal in Agra, India built around 1648 AD with high roof
(Source: Daview, 1987, pp. 160)

This type of architecture allowed the warm air to collect at the top and stratification of warm air maintains cool air at the floor level, thus maintaining air temperature in comfortable zone. Figure 2.21 shows the Taj Mahal in Agra India is a classical example of high roof building to achieve natural cooling. (Highfield, 1987, pp.161)

e. Double Roof

The technique includes two concrete ceiling one above the other with an air gap in between. The air gap acts as a thermal resistance for the heat flow from the roof exposed to direct sun, to the second slab below. Use of false ceiling is an example of this type of passive cooling. (Hirunlabh, 2001, pp. 162)

2.6.6 Exterior shading

(i) Landscaping

Landscaping is an effective and pleasant means of providing shades to the building. An effectively planned landscape will block out the hot sun, and channel breezes for cooling in summer. For example, trees, shrubs and groundcover plants can shade the ground and pavement around the house. This reduces heat radiation and cools the air before it reaches the walls and windows of the building. *"Large bush or row of shrubs shade a patio or driveway. Hedge is used to shade sidewalk. Trellis can be built for vines to climb to shade patio area. A lattice or trellis with climbing vines shades the home's perimeter while admitting cooling breezes to the shaded area."* (Rincon, 2001, pp. 111)

(ii) Roof overhangs

"Overhangs may be a permanent part of the building's structure, or may be used seasonally." (Szokolay, 2003, pp. 177) The importance of overhang according to Chand (1986) is they block direct sunlight and they should be used in conjunction with some other

cooling strategies such as interior shading to be fully effective. Overhang is useful to prevent rain entering the building but it is less effective to block direct sunlight due to angle of sun varied between different months.

(iii) Awning

"Awnings serve the same general function as an overhang, but are more flexible in their application." (Roaf, 2004, pp. 21) Made of lightweight materials such as aluminium, canvas, acrylic or polyvinyl laminate, it is possible for them to span distances of several feet without the need of extra support, thus making it possible for them to provide adequate shade even on the east or west. According to Raof (2004), "*awning is also designed to extend below the top of the window, increasing their shading effectiveness. To be more effective, awnings should be light in colour. Although awning is more effective than overhang, it is an additional to the building which will affect the aesthetic of the façade."*

(iv) Shutters and shades

"Exterior shutters and shades either hinged or of the rolling blind type, are another option for shading." (Hesketh, 1986, pp. 22) Although shutters and shades may block sunlight, however, they have a few disadvantages such as obscure the view from the window, block day lighting, and may be inconvenient to operate on a daily basis. They are also subject to wear and tear, and may block air flow.

(v) Interior shading

"Draperies and curtains are most effective when made of tightly woven, opaque material of a light or reflective colour." (Lippsmeier, 1969, pp. 24) Simple white roller shades

shade quite effectively when fully drawn, but prevent light and air from entering. Venetian blinds, while not as effective at trapping heat, will allow air and light to pass through, while reflecting some of the sun's heat. However, these screens will obstruct view and reduce daylight into the building.

(vi) Reflective Barrier

Several studies have been carried out regarding the cooling potential of the application of reflective coatings on buildings. White coloured coatings performed better than aluminium pigmented coatings. *"A 'cool' coating can reduce a white concrete tile's surface temperature under hot summer conditions by 4 degree Celsius and during the night by 2 degree Celsius."* (Aronium, 1991, Allen, 2003)

(vii) Wetted gunny bag covered roof

Wetted roof concept in which *"roof surface is wetted with wet gunny bags cloth and a continuous supply of water is assured to keep the surface wet."* (Hirunlabh, 2001, pp.90) Wetted gunny bag not applicable to hot and humid countries due to this technique utilized evaporative to cool building.

Table 2.4: Comparison between architecture techniques and passive techniques for cooling (Source: Author)

Architectural techniques		Passive techniques	
Domed & vaulted roof	Not suitable to apply in Malaysia due to our climate condition	Solar shading Landscaping	Building must have enough compound
Ventilated roof & Micro ventilated roof	Applicable for Malay house or building w/o ceiling	Roof overhangs	climatic design criteria
		Awning	Affect aesthetic façade
		Exterior shade screens	

High roof	Applied on old buildings *buildings in this research applied this technique	Reflective barrier	Light colour coating
		Wetted roof & Wetted gunny bag covered roof	Applicable for arid regions
Double roof	Applicable in modern building		

2.6.7 Passive cooling in modern buildings

Figure 2.22: LEO building in Putrajaya
(Source: Zakaria, 2006)

Naturally ventilated buildings may need special features, e.g. windows and openings strategically placed in the envelope, chimneys in the roof, envelopes designed with features such as extensions or fins to augment pressure differentials on the various windows, specially designed windows for manual or automatic control of natural ventilation. Currently some of the buildings in Malaysia also start implementing natural ventilation features, and there are some examples of buildings that incorporate more advanced features and may have an appearance that may look out of the ordinary to many people. Studies on how effective these additional features to allow natural ventilation into buildings had been conducted by several researchers. Site visit had been carried out at LEO building in Putrajaya on June 2010 as shown in Fig. 2.22. Through observation, the place especially at atrium area is not comfortable as the air is still although additional feature such as thermal flue had been inserted in the building. Thus, it is advisable to learn from our ancestors the essence of passive cooling in order to incorporate into modern design.

2.7 Critical barrier

There are obstructions in applying natural ventilation in buildings

Barriers during Building Operation	**Barriers during Building Design**	**Other Barriers**
- Safety - Noise - Air pollution - Shading - Draught - User ignorance	- Fire regulations - Acoustic regulations - Type of building use - Controls - Lack of suitable design tools	- Architectural impact - Lack of suitable standards - Increased risk for designers - Fee structure for design
Key Objective is to create improved thermal comfort in summer at low energy		

Figure 2.23: Overview of potential barriers to the application of natural ventilation in buildings
(Source: Alison 2007, Mendler 2005)

There are many problems of user acceptability that may prevent building occupant from implementing natural ventilation in a building. Figure 2.23 showed overview of potential barriers of application natural ventilation in buildings. Refer to Alison (2007), the most important barriers are the following:

- *Safety concerns,* i.e. preventing unauthorized entry of other people of animals, including bugs and insects or preventing rain from damaging the furnishings
- *Noise pollution*, which may interfere with normal activities and sleep or unpleasant
- *Air pollution*, from urban pollution to dust in the countryside, from harmful chemicals to simply bad odours

- *Shading for solar control*, that may require partial or total covering of openings provided in the outer envelope for natural ventilation
- *Draught prevention*, stemming from comfort or from work requirements
- *Ignorance of occupants* who do not familiar with taking the best advantage of natural ventilation

2.7.1 Internal Obstruction - *Barriers during Building Design*

The most common passive design obstacles designers' faces are the following: regulations in general and fire regulations, the pattern of use foreseen for the building, the need to provide shading, privacy and day lighting, the lack of suitable, reliable design tools as per stated in studies done by Alison (2007).

Table 2.5 showed summary of possible solution for external and internal obstructions (Source: Author)

External obstruction	Possible solution	Internal obstruction	Possible solution
Safety concern	Apply more louvers which allow natural ventilation	Pattern of foreseen for building	Check on local plan before deciding on location of opening
Noise from outdoors	Plant vegetation	Shading, privacy & daylight	Applies louver
Air pollution	Fixed window that allow daylight	Lack of suitable, reliable design tools	Get consultation from experts
Shading	Allocate window properly and omit additional shading		
Ignorance by occupants	Designers should advise on the appropriate locate of openings		

2.8 Day lighting

The use of natural light, or daylighting, has traditionally been a desirable building feature of good design. Based on Guzowski (2000) and Kleunne (2003) studies showed that day lighting design has recently taken on a new importance, beyond these aesthetic and psychological aspects, with the advent of energy shortages and sustainability concerns.

There are two sources for day lighting: top lighting (day lighting through skylights, roof monitors, etc.) and side lighting (day lighting through vertical windows at the building perimeter). Top lighting is shown in Figure 2.24 allows even levels of diffuse light to be distributed across large areas of a building. Side lighting is shown in Figure 2.25 tends to be more complex. *"Size, location, visual transmittance, and energy performance characteristics of glazing must be carefully refined. Glare control, involving window overhangs, interior light shelves, glazing choices, as well as interior shades or blinds, is critical. Daylight illuminance drops off with distance from the windows."*(Bowyer, 1980, Ander, 2003)

Figure 2.24: Top lighting sample
(Source: Kleunne, 2003, pp.58)

Figure 2.25: Side lighting sample
(Source: Bowyer, 1980, pp.60)

It is important to distinguish between sunlight and daylight. Refer to studies done by Bowyer (1980) shown that in most situations, direct sunlight brings excessive heat and light leading to visual and thermal discomfort. Thus, skylights designed to provide daylighting should contain diffusing glazing.

2.8.1 Daylight factor

According to Rea (2000), *"daylight factor is a numerical ratio used to described the relationship between indoor and outdoor daylight illuminance. The daylight factor depends upon a number of design factors including:*

- *Size of daylight apertures (windows, skylights, etc)*
- *Location of daylight apertures (side lighting, top lighting, etc)*
- *Access to daylight (considering the site, building, and room context)*
- *Room geometry (height, width, and depth)*
- *Visible transmittance (VT) of glazing*
- *Reflectance's of room surfaces and contents*
- *Reflectance's of exterior surfaces affecting daylight entering the aperture*
- *The effects of daylighting enhancements (such as light shelves)"*

2.9Bioclimatic Architecture

Bioclimatic architecture, or using external conditions for internal climate control in Ken Yeang's work, where his buildings contribute to their own environment, producing energy rather than merely consuming it. Research suggests that bioclimatic buildings will use five to six times less energy than conventional buildings over their lifetime (Yeang, 1995, pp. 45). This is achieved primarily through the use of the buildings' microclimate, form and fabric, rather than through the use of efficient mechanical equipment. For example, in warm climates where cooling is needed most of the year, 34% of energy is used to address the need for cooling to mitigate heat gain from solar radiation. In many cases this is due to poor design of the buildings envelope. (Yeang, 1996, pp. 94)

The zero energy building is an ideal concept where no fossil fuels are used and sufficient electricity is generated from natural sources to meet the service needs of the occupants. (Yeang, 1995, pp. 3) This idea sets the optimal design target for a building in terms of minimizing the environmental effect and minimum energy cost of the dwelling.

There are five types of buildings which categorised as bioclimatic design

Table 2.6: Characteristics of different types of buildings

1. Zero energy building	Utilized solar energy/renewable energy
2. Autonomous house	Harvest natural resources
3. Integer house	Similar to BAS where utilized IT to save energy
4. Eco Homes	Focus on utilized non fossil fuels to generate energy
5. SMART house	Universal design and take care of human needs

All mentioned above are MODERN techniques for passive cooling. They requested a lot of cost to build those types of houses which majority of residents are unable to afford.

2.9.1 Principles of Bioclimatic Design Housing

Refer to study done by Yeang (1996), the notion of bioclimatic housing can be defined not only in terms of environmental criteria, but also in terms of design principles. These principles are: creating user health and well-being, using passive systems, restoring ecological value, utilising renewable energy, utilising sustainable materials.

2.9.2 Investigate Case Studies

For the purpose of design checklist for simulation, buildings of case studies had been analysed and described. In this section, selected building had been examined in terms of site design, layout, and orientation, opening design, shading device, vegetation and thermal mass.

2.9.3 Design elements and Strategies of Bioclimatic Design

The main principle of bioclimatic design for passive and low energy buildings is to provide a comfortable environment by virtue of the passive features of design. A second principle is to use the active systems (mechanical equipment, such as air conditioning) with the passive systems to create an integrated solution for climate control.

Architectural means for minimising the heat gain of buildings, and consequently their cooling needs, generally would be less expensive than the application of cooling systems. The following architectural design features that affect the solar load on a building:

a. Site context

Before designing building, wind direction, orientation of the sun, access road (to identify source of dust and pollutants), and landscaping area should be justified.

b. Building layout

Buildings that are selected as case studies are single storey building in urban area. There is one of the case study which is located at a very dense urban area surrounded by high rise building. Subsequently, wind flow for the building had been obstructed.

c. Orientation of main rooms and windows respect to wind direction

(Building form & orientation, form of building envelope, building height, roof form) - Buildings that are selected as case studies are mostly L shaped. They are all single storey buildings, pitched roof and have overhang to protect occupants' from rain and sun. Refer to study done by Sharma (1994), aspect ratio is 2:1 (height: width). To encourage cross ventilation, width / depth of room should be small to create positive pressure for suction effects. In order to minimize variables, all the building selected for case study will be single storey. Roof for case studies pitch more than 15 degree, therefore the wind angle is perpendicular to eave line and create a positive pressure. As for horizontal distribution, it was noted that living room for case studies are mostly windward side while bedrooms, kitchen and bathroom are leeward side.

d. Window size, location and details (airflow pattern)

Windows in buildings selected for case studies are mostly side-hinged casement window. Research need to be conduct to investigate the wind flow through different types and size of windows in case studies

e. Shading devices for windows (screens, doors, vents, ventilators, attic ventilation)

Buildings selected for case study have interior screen which is vertically operating curtains and louvers

f. Colour of the building's envelope

All of the case studies interior and exterior are light in colour

g. Vegetation near the building

This factor important in determine microclimate of the site

h. Thermal mass (lightweight / heavyweight material)

All of the case studies are heavyweight building

Summary for buildings selected for case studies (mark ‘x’ for relevant)

Table 2.7: Summary of types of screens used for case studies

Exterior screen		**Interior screen**	
Rolling blinds		Venetian blinds	
Sliding sash		Curtains	x
Shutter		Louvers	x
Side hinged casement	x	Doors	x
		Vents & ventilators	
Colour envelope	Light colour	**Opaque elements**	Heavyweight

2.10 Simulation Software

There are a few simulation software to test for building performance:

1. ECOTECT – mostly used to calculate annual solar radiation, test shading devices, predict thermal loads within each building.

2. Energy Gauge (v.2008) and eQuest (v. 3.6) – to quantify overall energy consumption and overall cost which not suitable in this study.

3. DEROB-LTH – to explore the complex dynamic behaviour of buildings for different designs. The behaviour is expressed in terms of temperatures, heating and cooling

loads and different comfort indices. This study more emphasized in air flow, air exchange rate compared to thermal loads.

4. AIOLOS- calculation of the airflow rate in natural ventilation configurations, to assess air flow efficiency, sensitivity analysis for the investigation of the impact of specific parameter on natural ventilation, optimization for the derivation of the appropriate opening sizes for achieving optimum airflow rates in the investigated configuration which makes the software so unique. Testing of the model consists of evaluating the existing condition, testing for the air changes/air flow rate and testing for the effects of including different opening sizes in the house.

5. SUMMER – designed by Santamouris to dealt with natural and passive cooling techniques. This software designed by same author of AIOLOS and its function similar to AIOLOS but this software more focus on passive cooling techniques.

Therefore, among all software mentioned above, AIOLOS was suggested to be used for this case study, more explanation on the software will be presented in Chapter 3.