GREEN BUILDING INDEX – MS1525

Applying MS1525:2007 Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings

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1. FACTORS AFFECTING ENERGY USE IN BUILDINGS

1.1 Overview of Factors Affecting Energy Use in Buildings

The factors affecting energy use in buildings can be categorized into two groupings

END –USE : Air Conditioning & Space Heating
Lighting
Power & Process

FACTORS : Occupancy & Management
Indoor Environmental Quality
Climate
Building Design & Construction
Mechanical & Electrical Equipment

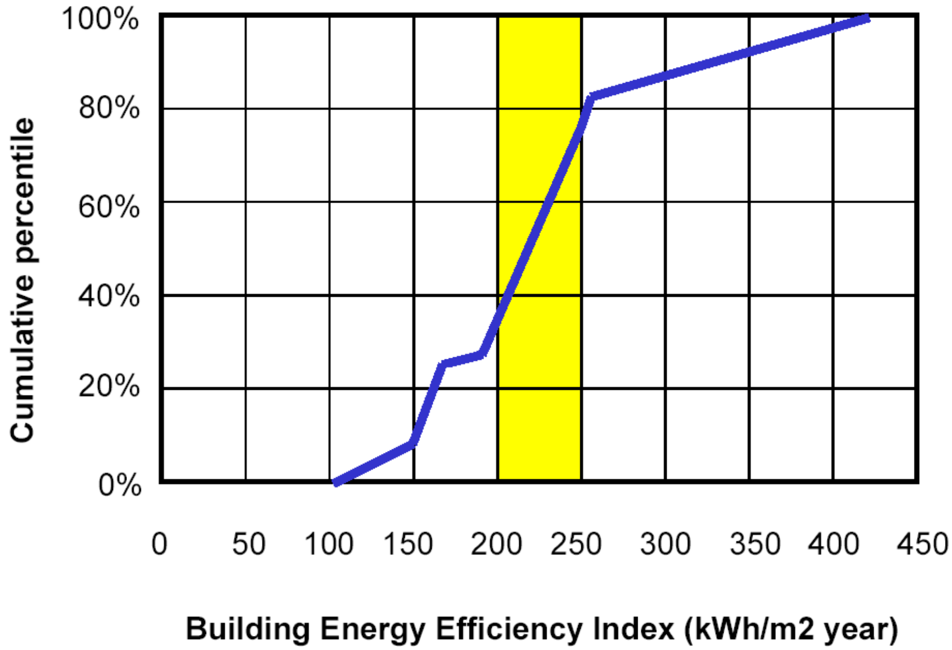
1.2 Building Energy Indices

Before going into details of the factors affecting energy use, some method of comparing energy use - the energy use indices – will be explained. The index selected would depend on the intended application of the index and the normalizing factor. Among Architects the normalizing factor for comparing buildings is the gross floor area. The most commonly used index for comparing energy use in buildings is therefore the Building Energy Use Index - BEI. This is usually expressed as kWh/m2/year which measure the total energy used in a building for one year in kilowatts hours divided by the gross floor area of the building in square meters.

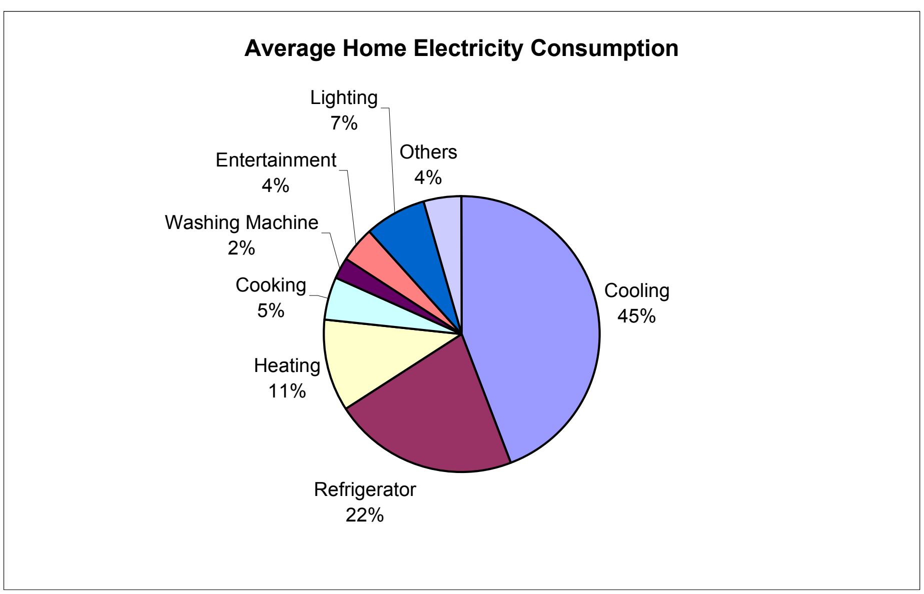
1.3 End Use & Actual Energy Consumption

The amount of energy used in buildings depends firstly on WHAT IT IS USED FOR. Thus the initial and most important step in isolating the factors affecting energy use is to determine its end-use. To architects, the category of use or building type will be the first factor to consider. Therefore to compare the energy index of say an office building which operates from 9 am to 5 pm to say a data processing center which operates computers around the clock would not be a reasonable comparison because the operating hours are different and the computers in the data processing centre would consume more electricity and may require a higher environmental standard. Comparing two schools in the same climatic region and similar operating conditions would however give a comparison of the energy performance of the two buildings.

The energy audits carried out by Pusat Tenaga Malaysia, PTM , of Office buildings in Malaysia revealed that the majority of Malaysian Office buildings had BEI in the range of 200 to 250 kWh/m2/yr. Similar results were found in Singapore, with very few buildings

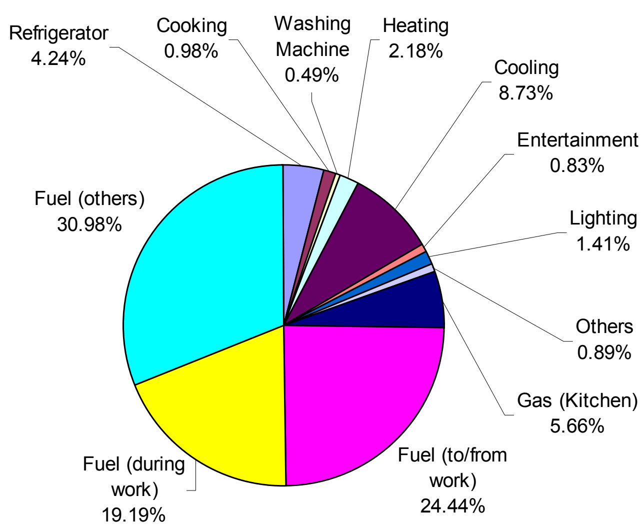


A 2006 study of Household Energy use by CETDEM – Center for Enviroment, Technology & Development, Malaysia - headed by Ir Gurmit Singh in cooperation with Majlis Bandaraya Petaling Jaya and funded by Exxon Mobil found the following.



Air conditioning and the refrigerator take up nearly 70% of the average household electricity consumption and air conditioning is the largest consumer of electricity in the home. With the threat of “Global Warming” and increasing energy cost, keeping the home cool will become increasingly important in the future. More interesting is the findings by CETDEM that close to 75% of a household's energy consumption in the survey is in the form of petrol for getting to work and non-work related petrol consumption, as shown in the chart below. The planning of our future townships and cities, the spread of densities, the location of essential amenities and the layout of the major public transport routes to more efficiently and better serve the communities will become critical issues that will determine the quality of our future communities.

Average Household Energy Consumption



1.4 Non Design Factors affecting Energy Use in Buildings.

From the results of my own studies on energy use in New Zealand Schools, the following were found to have a significant impact on energy consumption in buildings.

Occupancy and Management - It should be emphasized that people use energy. The building itself does not use much energy. We cool or heat the people in the building, not the building. There are four broad aspects to consider.

1. intensity of building occupancy
2. activity type
3. user attitude and behavior
4. management and organization

First, the amount of energy used will generally be directly proportionate to the intensity of building occupancy. An office building rented out for only half a year will obviously use half the energy of an equivalent building occupied throughout the year. Operating hours will be another normalizing factor energy auditors must keep track of

Second, the level of physical activity, the clothing worn, the duration of occupancy and age, size and background of the occupant will also affect the cooling / heating requirement. These factors will affect cooling requirements by influencing the preferred air temperature. Fanger and Kowakzewski's work show for example that a person wearing light clothes and doing light desk work seated will feel comfortable at 25 degrees centigrade while he will only feel comfortable at 21 degrees centigrade with a light business suit. This 4 degrees difference can mean a 100% difference in the air conditioning energy requirement of a room.

Third, the attitude of the occupants towards energy use has significant consequences. They are influenced by the aims and goals of the uses, the penalties and benefits to the user of conserving energy, expectations of the user and weather the users are aware of the relationship of their actions to the amount of air conditioning of heating energy used

Finally, the organization and management of the building and its air conditioning equipment I terms of operation and maintenance will reflect on its efficiency and thus the energy used.

Indoor Environmental Quality – The amount of air conditioning load required and thus air conditioning energy used depends very much on the air temperature maintained in the building. Some office buildings and hotels maintain indoor temperatures as low as 18 to 20 degrees centigrade when the comfortable temperature is about 24 degrees centigrade. There are many office buildings in Malaysia where the indoor temperature is so low that the occupants wear sweaters at the work desk. It is obvious the owners are no aware of the cost implications of their actions. It should also be noted that the average outdoor air temperature in Malaysia is only about 4 degrees above the comfort range.

Climate – The number of publications and studies of the relationship of climate to architecture, people and energy use is very extensive. The purpose here is only to list some of the variables of concern.

Climate affects the energy consumption in a building primarily by influencing the space cooling and heating requirements. The main climatic variables influencing the amount of energy needed for air conditioning are.

1. Solar radiation
2. Outside air temperature
3. Wind and rain
4. Night sky radiation

Geiger has an extensive study of the physical variable influencing the microclimate. This would be useful for those planning large scale developments. The table below lists the major physical factors influencing the climate, some of which may be within the Designers control.

	Solar Gain	Temperature	Wind
MACRO CLIMATE			
Latitude	Major	Major	
Altitude	Minor	Major	Minor
MICRO CLIMATE			

Terrain - Slope	Minor	Minor	Major
Ground Cover - Vegetation		Minor	Major
City / Country – Shading / Shelter	Minor	Minor	Minor
Water Body – Inland / Seaside		Minor	Minor

Site Planning & Microclimate

The following topographic factors have been found by Geiger (3) to influence the microclimate around a building, and ultimately its cooling energy requirement.

1. Altitude
2. Terrain
3. Water Body
4. Natural Cover
5. Cities

ALTITUDE – Temperature in the atmosphere decreases with increasing altitude by approximately 1 degree centigrade per 180 meters in the tropics and summer in the temperate regions and 1 degree centigrade per 220 meters in winter conditions

TERRAIN – Cool air is heavier than warm air, and at night the outgoing radiation causes a cool air layer to form near the ground surface. The cool air behaves somewhat like water, flowing towards the lowest point. This “flow of cool air” causes “cool island” or “cool air puddles” to form in valleys.

Accordingly, elevations that impede the flow of air effect the distribution of nocturnal temperatures by dam action and concave terrain formations become cool-air lakes at night. The same phenomenon is enlarged when a large volume of cool air flow is involved, as in valleys. The plateaus, valley walls and bottom surfaces cool off at night. Air flow occurs towards the valley floor. On the valley slopes, a series of small circulations mix with the neighboring warm air, causing intermediate temperature conditions. Accordingly, the temperature at the plateaus will be cool, at the valley floors very cool, but the high sides of the slopes will remain warm. This area often indicated by the difference in vegetation, is referred to as the warm air slope (thermal belt).

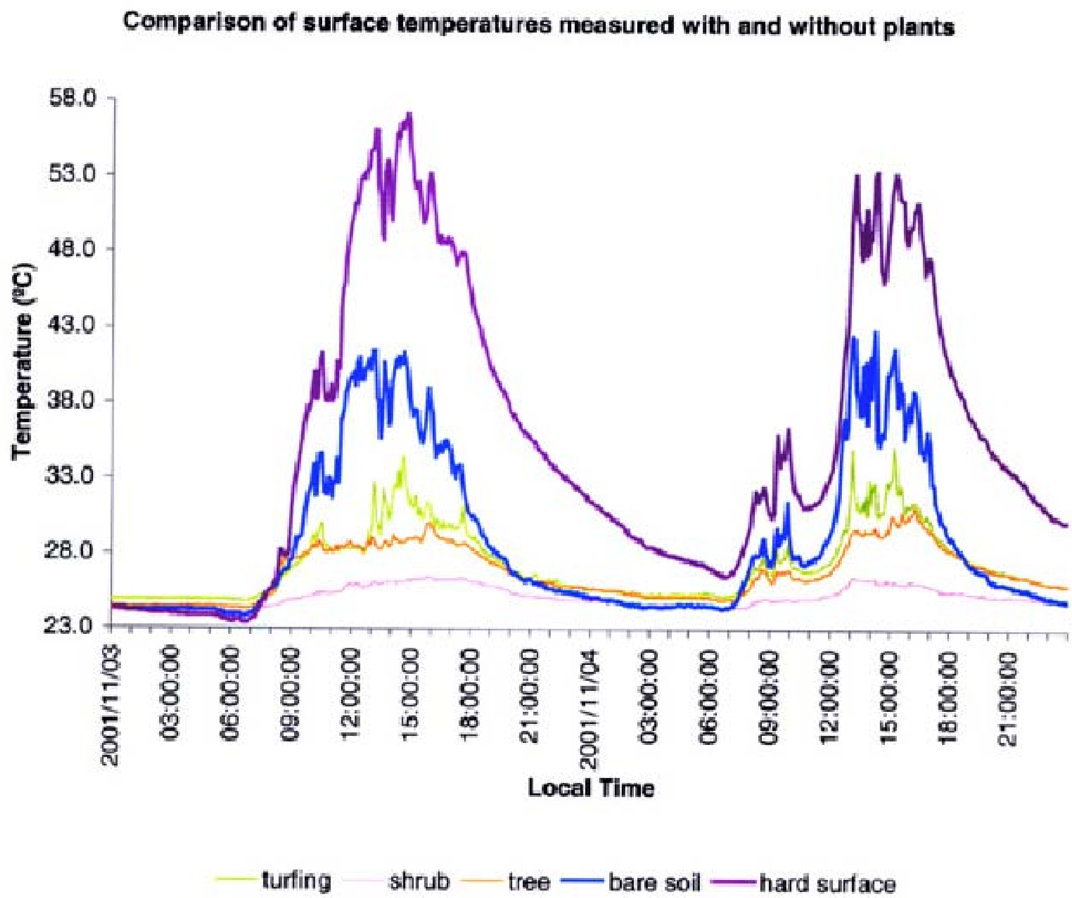
WATER BODY – Water having a higher specific heat than land, is normally warmer in winter and cooler in summer and usually cooler in during the day and warmer at night, than land. Accordingly, the proximity of bodies of water moderates extreme temperature variations and lowers the peak temperatures in our tropical climate.

In the diurnal temperature variations, when the land is warmer than the water, low cool air moves over the land to replace the updraft. During the day, such offshore breeze may have a cooling effect of about 5 degree centigrade. At night the direction is reversed. The effects depend on the size of the water body and are more effective along the lee side.

NATURAL COVER – The natural cover of the terrain tends to moderate temperatures and stabilize conditions through the reflective qualities of various surfaces.

Plan and grassy cover reduce temperatures by absorption of insulation, and cool by evaporation. It is generally found that temperatures over grassy surfaces are 5 to 7 centigrade degrees cooler than those of exposed soil. Other vegetation may further reduce high temperatures; temperatures under a tree at midday can be 3 degrees centigrade lower than in the unshaded environment. Conversely, man-made surfaces tend to elevate temperatures, as the materials used are usually absorptive in character. Asphalt surfaces can reach 51 deg.C in 37 deg.C air temperatures.

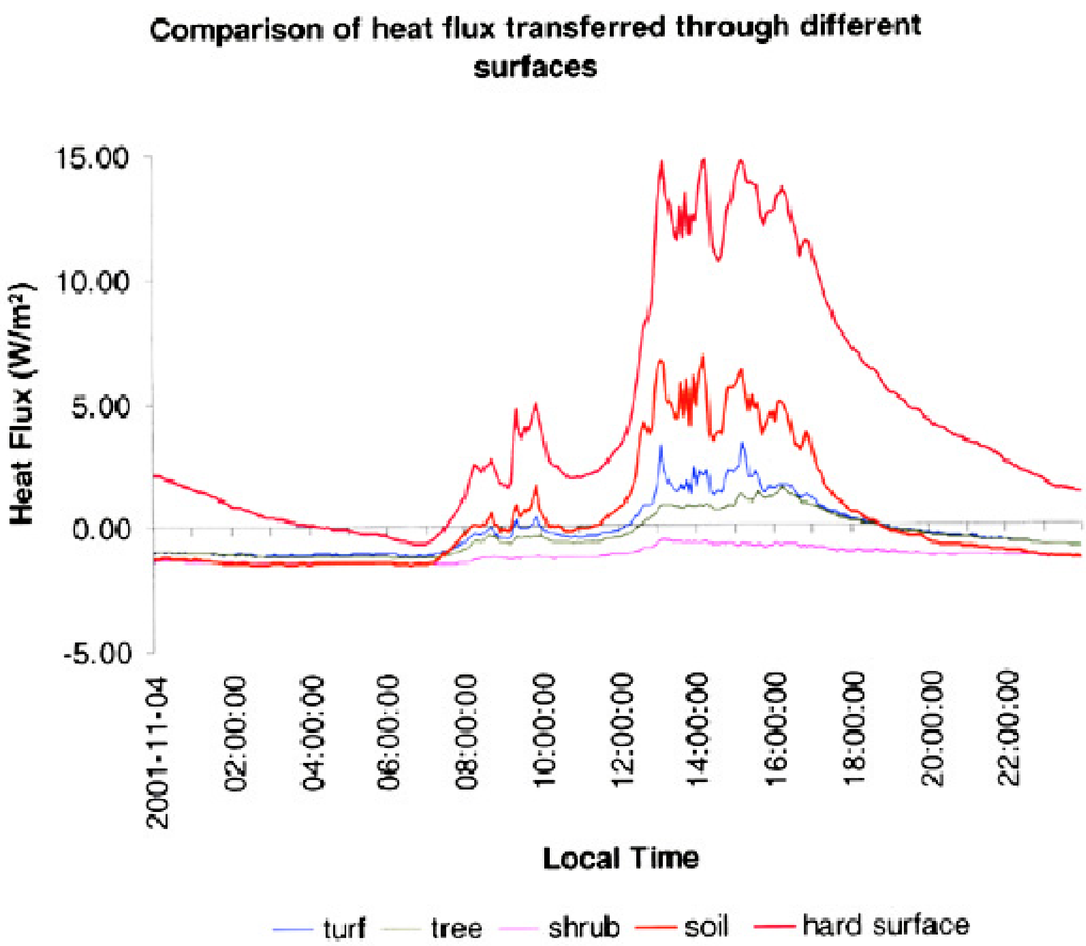
The measurements taken by Professor Wong Nyuk Hien of the National University of Singapore shows the extent of the effect plantings have on the urban surface temperatures. The results of his case studies are quoted below.



This shows that plants play an important role in reducing thermal heat gain due to their sun-shading effects during the daytime. For most plants, negative heat flux was found not only at night but also during the period when the solar radiation were not very strong during daytime. That is, the shading effects of plants is so good that they don't just reduce heat from entering buildings but actually resulting in heat loss from the building.

Plants contribute to creating better outdoor thermal environment and mitigating the Urban Heat Island effect. The ambient air temperatures were also measured at different heights above the hard surface and the vegetation part respectively on the rooftop of the commercial building. The 'cooling effect' of plants could be found from afternoon to sunrise next day. The maximum temperature difference was 4.2ºC, measured at 300mm height, around 1800 h. This shows that plants on rooftop gardens can reduce ambient temperature by as much as 4 ºC.

Foliage of plants affects temperature readings. Under dense shrubs, surface temperature remains stable, with less than 3 ºC daily variations. The maximum surface temperature was only 26.5 ºC. The direct thermal effects of plants were further evaluated by measuring the heat flux through different types of roofs as shown in the diagram below. The heat flux was for hard surface, bare soil (without any plants), turf, tree, and shrub respectively.



CITIES – Cities tend to be warmer than the surrounding countryside. That cities differ from the countryside not only in their temperatures but also in many other aspects of climate is widely recognized. The city itself is the cause of these differences. Five basic influences set a city's climate apart from that of the rural area.

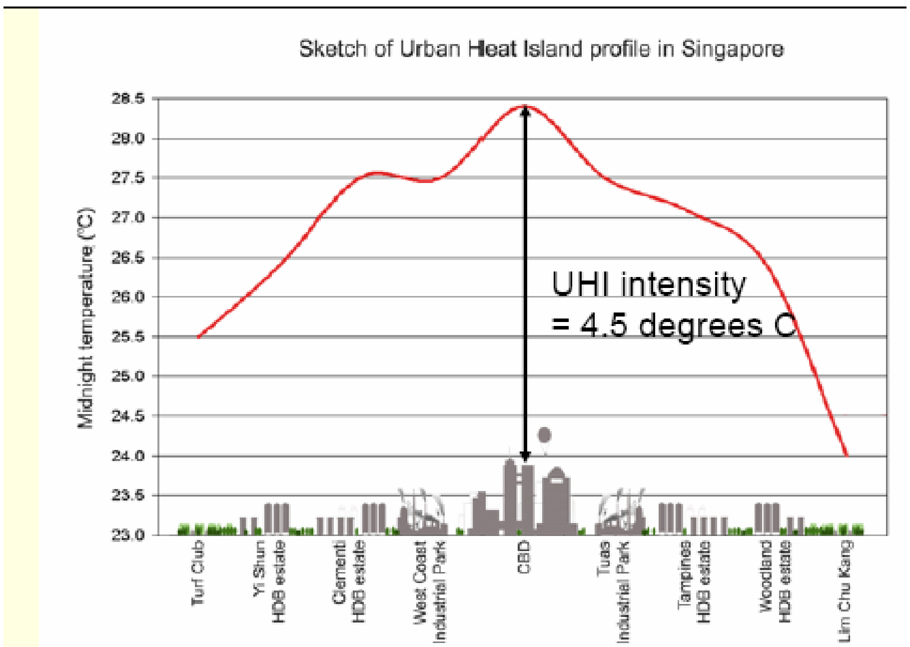
First, there is the difference in surface materials. The predominantly rocklike materials of the city's buildings and streets can conduct heat about three times as fast as it is conducted by wet sandy soil. This means that the city's materials can accept more heat in less time, so that at the end of a day the rock like material have stored more heat than an equal volume of soil.

Secondly, the city's structure have a greater variety of shapes and orientations and function like amaze of reflectors, absorbing some of the solar radiation and directing much of the rest to other absorbing surfaces, so that almost the entire surface of a city absorbs and stores heat. In forest and open areas on the other hand, the heat tends to be stored in the upper part of plants. Since air is heated almost entirely by contact with warmer surfaces rather than by direct radiation, a city is more efficient in using sunlight to heat large volumes of air.

Third, the city is a prodigious generator of heat. Among these are factories, cars and people. A study of Manhattan by Griffiths (4) suggested that the heat produced by combustion alone is 2.5 times greater than the solar heat gain

Fourth, the city has a higher run-off of rain water. In the country, rain water remains on the surface or immediately below it. The water is thus available for evaporation, which is of course a cooling process. Because there is less opportunity for evaporation in the city, it loses less heat.

Finally, the city air has a heavy load of solid, liquid and gas contaminants. These tend to reflect sunlight, reducing the amount of heat reaching the surfaces, but they also retard the outflow of heat resulting in higher peak temperatures.



1.5 Passive Design Factors affecting Energy use in Buildings

The building layout, planning, design, shape, fabric and construction cover a wide number of variables that affect building energy requirements. This the area where the basic decisions of the architect will have the most influence on the building's energy use. How much then does the designer have? The following sets of estimates by Givoni should serve to illustrate a building's influence on its indoor environment and thus air conditioning or heating requirement. Depending on the design

1. the indoor air temperature amplitude – swing from lowest to highest – can vary from 10% to 150% of outdoor amplitude
2. the indoor maximum air temperature can vary by -10 to +10 deg.C from outdoor maximum
3. indoor minimum air temperature can vary by 0 to +7 deg.C from outdoor minimum
4. indoor surface temperature can vary by +8 to +30 deg.C from outdoor maximum and minimum.

The building related factors influencing energy requirements are numerous and complex. They can be classified under the following headings.

1. Size and Shape
2. Orientation
3. Roof System
4. Planning and Organization
5. Thermo physical properties – thermal resistance & thermal capacity
6. Window systems
7. Construction detailing.

Size and Shape – Generally, a larger building will require more energy to cool than a smaller building because of the larger of space to be cooled. This is widely accepted. The question of whether a building needs less energy per unit volume or floor area is however a more complex one and still not completely resolved. Many theoretical researchers take the view that larger buildings need less energy per unit size because of their smaller surface area per unit size and thus lower heat gain per unit size. Based on this theory they say " The larger a building, and the nearer to spherical in shape, the less are its energy needs because of the simple reduction in the ration of surface area to volume". They conclude that "The architectural fad for angular protrusions of buildings is an energy wasting form".

The Building Research Unit however found from field data that compact buildings cost more to erect and had higher energy running costs than sprawling ones. These empirical findings were contrary to the Unit's theoretical predictions. They concluded that the quality of "compactness" in layout is one which cannot, on present evidence, be shown to be of paramount importance. Stein reach conclusions similar to the BPRU " …the maximum volume, minimum perimeter building will not be the most energy conservative and because of the mechanical systems required to provide interior comfort conditions at all times, may not even be the least expensive."

Building Orientation – Building orientation affects the air conditioning / heating energy requirements in two respects by its regulation of then influence of two distinct climatic factors.

1. Solar radiation and its heating effects on walls and rooms facing different directions
2. Ventilation effects associated with the relation between the direction of the prevailing winds and the orientation of the building.

Of the two, solar influence on energy is the most significant in the tropics and is extensively covered by many others.

The table below compares the approximate daily solar gain for some typical Malaysian housing types.

SOLAR HEAT GAINS IN TYPICAL MALAYSIAN HOUSING

	Single Storey Terrace	Double Storey Terrace	Five Storey Flats	Eight Storey Apartments
Gross Floor Area	880	1,408	60,500	81,680
Unit Floor Area	880	1,408	750	850
Volume	14,080	18,304	665,500	898,480
Roof Area	1,012	792	12,100	10,210
Wall Area	484	968	28,050	47,872
Envelope Area	1,496	1,760	40,150	58,082
Roof/Envelope Area	68%	45%	30%	18%
Wall/Envelope Area	32%	55%	70%	82%
North-South Fronting				
Roof Solar Gains	30	24	363	306
NS-Wall Solar Gains	5	10	198	356
EW-Wall Solar Gains	0	0	165	246
Total Solar Gains-kWh/day	35	33	726	908
Total Solar Gains-kWh/m2	0.04	0.02	0.01	0.01
East-West Fronting				
Roof Solar Gains	30	24	363	306
NS-Wall Solar Gains	0	0	83	123
EW-Wall Solar Gains	10	19	396	711
Total Solar Gains-kWh/day	40	43	842	1,141
Total Solar Gains-kWh/m2	0.46	0.31	0.14	0.14
Increased Solar Gain Percent	14%	29%	16%	26%

For an intermediate single storey terraced houses, where the roof makes up nearly 70% of the building envelope exposed to the sun, roof insulation becomes all important to keep the home cool. Orientation has less of an effect the difference in solar radiation for a north-south and east-west facing being only about 14%

An intermediate double storey terrace house however has significantly more wall area and orientation will have a significant effect on the solar gain, being nearly 30% more for an east-west facing house.

For flats and apartments, depending on the aspect ratio and height of the building, an east west facing building can have 16% to 40% more solar gain than a north-south facing block.

What can the Architect do to reduce this solar heat gain? The following are some suggested ideas.

1. Orientate the largest wall areas in the north-south direction
2. Locate service areas such as staircases, store rooms and service ducts in the east-west external walls.
3. Place as many service rooms on the roof top of flats as possible to reduce the solar gain through the roof.
4. Sky lights should not be used. If roof ventilation is required, use a jack up roof facing the north.
5. Shade east-west facing walls with large roof overhangs or plant shading trees in front of them.

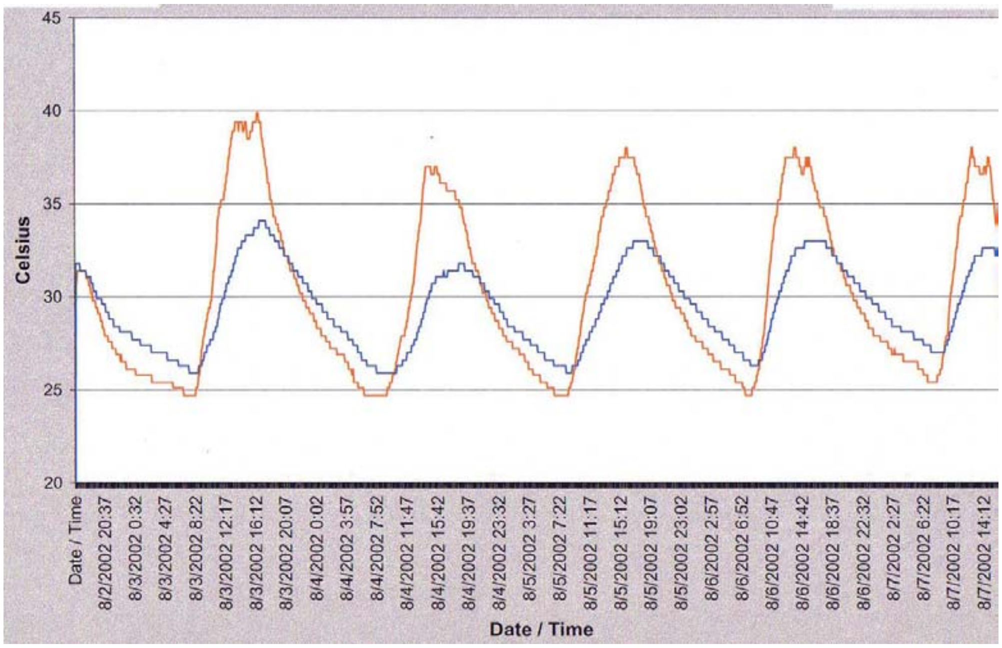
Roof System

The typical Malaysian terraced house receives most of its solar heat gain from the roof. This is because the horizontal surface receives the highest solar radiation, peaking at about 350 Wh/m2 at mid-day in the tropical sun and it continues to receive the highest solar radiation level throughout the day. Add to that the higher ratio of roof to building envelope area; the typical roof receives from 50% to 85% of the total solar radiation as shown in the table below.

SOLAR HEAT GAINS IN TYPICAL MALAYSIAN HOUSING

	Single Storey Terrace	Double Storey Terrace	Five Storey Flats	Eight Storey Apartments
Gross Floor Area	880	1,408	60,500	81,680
Roof/Envelope Area	68%	45%	30%	18%
Wall/Envelope Area	32%	55%	70%	82%
North-South Fronting				
Roof Solar Gains-kWh/day	30	24	363	306
Total Solar Gains-kWh/day	35	33	726	908
Roof/Total Solar Gains	86%	71%	50%	34%
East-West Fronting				
Roof Solar Gains-kWh/day	30	24	363	306
Total Solar Gains-kWh/day	40	43	842	1,141
Roof/Total Solar Gains	76%	55%	43%	27%

Reducing the solar heat gain through the roof should therefore be the first priority for keeping the home cool. Measurements by “Lafarge Roofing” have found peak temperatures differences between a roof insulated and an not insulated to be as much as 4.5 deg.C



For sloping roofs the following if implemented correctly can reduce inside temperatures by as much as 4 degrees centigrade.

1. Use lighter coloured roofing or better still slightly reflective type roofing.
2. Apply aluminium foil insulation under the roof tile to reduce radiant heat gained by the roofing from being radiated to the ceiling.
3. Ventilate the loft area above the ceiling and below the roof tiles. Measurements taken in this loft area have been found to go as high as 45 deg.C for outside air temperature of 35 deg.C for not insulated roofs.
4. Apply a layer of rock wool insulation immediately above the ceiling to prevent the heat from the loft area fro being radiated and conducted into the living area immediately below the ceiling.

Planning & Layout – It is not possible to generalize or quantify the complex implications that planning and layout of spaces will have on air conditioning and lighting requirements. Some areas where the layout will influence are listed below.

1. Grouping of spaces
2. Interaction of spaces
3. Ceiling height and space volume
4. Buffer zones

Thermo Physical Properties – The properties of materials which affect the rate of heat transfer in and out of a building, and consequently the air conditioning or heating energy requirements are.

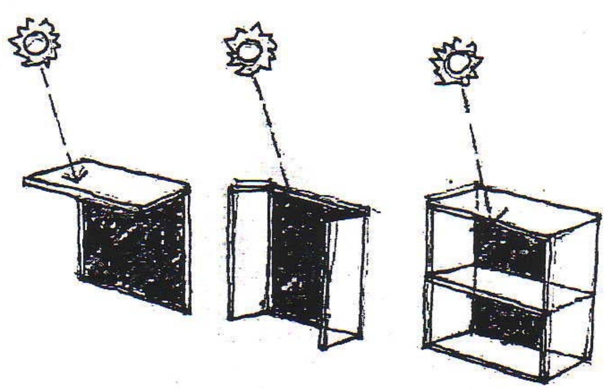
1. Thermal Resistance
2. Surface Convective coefficient
3. Absorptivity, Reflectivity and Emissivity
4. Heat Capacity

Window Systems – The size, location, shape and orientation of glazed areas in a building will have a critical effect on both the heat gains and solar gains of a building because glazed areas have the highest hat gain per unit area and the major proportion of solar gains are also through windows. The importance of this factor is indicated by Stein's finds that the school with the highest energy use per square foot in New York City was a completely sealed building with windowless classrooms.
The amount of heat gins will also be influenced by

1. Type and design of shading system employed
2. Composition and type of glass
3. Obstruction and shading by surrounding buildings, structures and trees

For tropical climates, external shading devices or recessed windows have been found to be the most effective method of reducing solar heat gains through windows without losing the significant benefits of day lighting.

The recommendations by Assoc Prof Dr Ku Azhar Ku Hassan of University Science Malaysia should serve as a useful guide to Architects.



1. Horizontal shading devices is generally effective against high sun at both east and west orientations
2. Vertical shading is generally effective for south orientations
3. Egg-crate shading devices is the generally effective for all the orientations

Construction Detailing – This will influence air conditioning loads in the following areas.

1. Infiltration cold air losses at junctions of different materials especially between roof joist and exterior walls, similar to the effect of leaving the door open in an air conditioned room
2. Conduction bridges – These are paths through which heat gain will be greatest, for example through a metal deck roof on a steel roof truss directly into the top floor of air conditioned spaces.

Summary

1. The amount of energy used in buildings depends on WHAT IT IS USED FOR
2. Data on the actual energy consumption in Malaysian Office Buildings audited by PTM show that typical Malaysia Office Building consumes about 250 kWh/m2/year of energy of which about 64% is for air conditioning, 12% lighting and 24% general equipment.
3. The major non design factors influencing energy use in buildings are 1. Occupancy & Management, 2. Environmental Standards, 3. Climate
4. Major building related factors influencing energy requirements can be classified under the following headings.
    1. Size and Shape
    2. Orientation
    3. Planning and Organization
    4. Thermo physical properties – thermal resistance & thermal capacity
    5. Window systems
    6. Construction detailing.
5. When amended, the UBBL will require air conditioned buildings Non-residential buildings larger than 4,000 square meters in floor area to have OTTV not more than 50 W/m2
6. Site surrounded with proper landscaping and water bodies can reduce the microclimate temperate from between 4 to 7 deg.C
7. Roof top gardens with shrubs can reduce the heat flux through the roof by more than 10 times compared with bare concrete roofs.
8. North and South oriented walls receive between 100 to 130 wh/m2 of solar radiation compared to 300 Wh/m2 for east and west facing walls. Depending on the building type and shape, a north-south oriented building can receive approximately 15% to 30% less solar gain than an east-west oriented building.
9. Locate low occupancy rooms on the west side of the home such as store and staircases.
10. The roof is the surface which receives the highest amount of solar radiation through the day. Insulating the roof is therefore vital in reducing air conditioning load. Peak temperatures can be reduced by 5 to 7 deg.C
11. Aerated lightweight concrete blocks have thermal resistance 3 times better than common sand cement blocks <1 w/m2K compared to >3w/m2K
12. Design Windows to block out direct sunlight. Let in the air and daylight. Diffused daylight gives more lumens per watt of heat produced than fluorescent lights.
13. External shading devices are more effective than internal blinds.
14. Horizontal shading devices are generally more effective against the noon sun at east-west orientations
15. Vertical shading is only effective for south facing windows
16. Egg-crate and pineapple-skin type shading devices is the most effective type of window shading device and is suitable for all orientations

2. COMPLYING TO MS1525 : 2007
PASSIVE DESIGN ELEMENTS

2.1 Background to MS 1525 : 2007

In March 2005, Kementerian Tenaga, Air dan Kommunakasi – KTAK – had proposed to the Ministry of Housing and Local Government – KPKT - that the Uniform Building By-Law (UBBL) be amended requiring that the building envelope design of NEW air-conditioned NON-RESIDENTIAL buildings to meet requirements of MS1525 with regards to OTTV, daylight, RTTV. This new by-law has been scheduled to come into force in 2007.

What is MS1525 and what is OTTV? MS1525:2001 is the "Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-residential Buildings." MS1525 has recommended that the OTTV or "Overall Thermal Transfer Value" of a building should not exceed 50 W/m2. This is an index reflecting the thermal efficiency of a building. The higher the OTTV, the lower its thermal efficiency and hotter is the building during the day. A single storey office block with a metal deck roof without any insulation, for example, would not comply with this standard.

What then is the role of the Architect and Engineer in this? As outlined in Section 1, the Size and Shape of the building, its Orientation, Planning and Organization, its Thermo physical properties – thermal resistance & thermal capacity, its Window systems and its Construction detailing among others will all affect its OTTV. Under the amended UBBL, Architects and Engineers will be required to compute the OTTV using the indices provided in MS1525 and submit these to the relevant approving Local Authorities, ensuring that they comply with the 50W/m2 benchmark, when they submit their building plans for approval. When fully implemented, this will bring in an era of more energy efficient buildings in Malaysia which will consume not only less electricity for air conditioning but will also be cooler.

2.2 Basics of MS 1525 : 2007

What are the basic requirements of MS 1525?

- Architects and Engineers are required to comply with MS 1525 requirements for NON-RESIDENTIAL buildings with AIR CONDITIONED AREAS LARGER THAN 4000 SM after the UBBL amendment is made.
- New Office Buildings, Commercial Complexes, Government Buildings, Hotels with more than about 50 rooms, Hospitals with more than about 50 beds, Institutional buildings, High Tech Factories Colleges and Universities, among others.
- Normal shop-offices, non-air conditioned factories and warehouses, will not be covered under this standard.
- Architects will have to submit OTTV & RTTV calculations to show compliance with Section 5 of MS 1525
- Engineers will have to ensure compliance with sections 6,7,8 and 9 of MS 1525

Section 5.8 of the standard outlines the submission procedure.

The following information shall be provided by a professional Engineer or Professional Architect:

a) a drawing showing the cross-sections of typical parts of the roof construction, giving details of the type and thickness of basic construction materials, insulation and air space;
b) the U-value of the roof assembly;
c) the OTTV calculation; and
d) the RTTV of the roof assembly, if provided with skylights.

2.3 Building Envelope, window design & OTTV

Heat conduction through the overall building envelope can be computed by calculating its overall thermal transfer value (OTTV). The OTTV requirement is aimed at achieving the design of adequately insulated building envelope so as to cut down external heat gain and hence reduce the cooling load of the air-conditioning system. The OTTV concept takes into consideration the three basic elements of heat gain through the external envelope of a building, as follows.

1. heat conduction through opaque walls
2. heat conduction through glass windows
3. solar radiation through glass windows

The overall OTTV can be computed by the following formula outlined below extracted from the standard.

5.2.1 The OTTV of building envelope is given by the formula below:

$$OTTV = \frac{A_{o1}\ x\ OTTV_1 + A_{o2}\ x\ OTTV_2 \ldots\ldots\ x\ A_{on}\ x\ OTTV_n}{A_{o1} + A_{o2} \ldots\ldots + A_{on}} \quad \ldots\ldots \quad (1)$$

where,

A_{oi} is the gross exterior wall area for orientation *i*; and

$0TTV_i$ is the *OTTV* value for orientation *i* from equation (2).

5.2.2 For a fenestration at a given orientation, the formula is given as below:

$$OTTVi = 15\,\alpha\,(1 - WWR)\,U_w + 6\,(WWR)\,U_f + (194\ x\ CF\ x\ WWR\ x\ SC) \quad \ldots\ldots \quad (2)$$

Where,

WWR is the window-to-gross exterior wall area ratio for the orientation under consideration;

α is the solar absorptivity of the opaque wall;

U_w is the thermal transmittance of opaque wall ($W/m^2 K$);

U_f is the thermal transmittance of fenestration system ($W/m^2 K$);

CF is the solar correction factor; as in Table 1; and

SC is the shading coefficient of the fenestration system.

Although the mathematical formula may look very intimidating to many architects, we must try to remember that these methods were developed back in the mid 1980's and meant for calculating using only calculators. With the latest computer spread sheets, testing of different options would be a simple matter of extracting data from manufacture's catalogues and imputing the basic data in the U-values spread sheets and then transferring them to the OTTV spreadsheets.

What can Architects do to improve the OTTV of their building envelope and to comply with MS 1525? The following will serve as a useful guide.

1. Heat conduction through opaque walls, the first part of the formula in section 5.22 typically accounts for between 0.5 % to 5% of the overall OTTV. This will have a bigger impact if the window areas are small, such as in shopping complexes
2. Heat conduction through windows typically accounts for 10% to 20% of the overall OTTV, depending on the amount of glazing and if they are single or double glazed.
3. Solar radiation through glass windows is the greatest contributor to the OTTV typically accounting for between 70% to 85% of the overall OTTV, depending on the glazing area. The large constant of 194 already hints that this is a major factor in the overall OTTV. In order to keep the OTTV contribution for exceeding 50 w/m2, the shading coefficient is a major contributor to the overall OTTV as it can change this component by between 30% to 80% of OTTV.
4. Architects must however keep in mind not to use too much tinted glazing in order to bring up the SC, as section 5.4.2 requires that the daylight transmittance be more than 50%.

2.4 Roof Construction & RTTV

Roof insulation is one of the most important and lowest cost strategies for energy efficiency as most of the solar radiation on a building is on its roof surface.

- The roof plane receives the most Solar Radiation and for the longest period through the day
- >75% of the Solar Gain by a typical Intermediate Single Storey Terraced House is through its ROOF
- >50% of the Solar Gain by a typical Intermediate Double Storey Terraced House is through its ROOF
- >40% of the Solar Gain by a typical 5 Storey Bock of Flats is through its ROOF

MS1515 requirements for roof insulation are as outlined below.

5.5.1 The roof of a conditioned space shall not have a thermal transmittance (U-value) greater than that tabulated in Table 9.

Table 9. Maximum U-value for roof (W/m²K)

Roof Weight Group	Maximum U-Value (W/m²K)
Light (Under 50 kg/m²)	0.4
Heavy (Above 50 kg/m²)	0.6

5.5.2 If more than one type of roof is used, the average thermal transmittance for the gross area of the roof shall be determined from:

$$U_r = \frac{(A_{r1}\,U_{r1})\ x\ (A_{r2}\ x\ U_{r2})......+(A_m\ x\ U_m)}{A_{r1}+A_{r2}......+A_m} \qquad ......(4)$$

where,

U_r is the average thermal transmittance of the gross area (W/m^2 K);

U_{r1} is the respective thermal transmittance of different roof sections (W/m^2 K); and

A_{ri} is the respective area of different roof sections (m²).

The average weight of the roof is calculated as follows:

$$W_r = \frac{A_{r1} \times W_{r1} + A_{r2} \times W_{r2} ..... + A_m \times W_m}{A_{rt} + A_{r2} ..... + A_m} \quad .....(5)$$

where,

W_r is the average weight of roof (kg/m^2);

A_{ri} is the respective area of different roof sections (m²); and

W_{ra} is the respective weight of different roof sections (kg/m^2).

5.5.3 If the roof area is shaded from direct solar radiation by ventilated external shading devices such as a double ventilated roof, the U-value may be increased by 50 %.

5.5.4 If external roof surface reflective treatments are used where the solar reflectivity is equal to or greater than 0.7 and the treated surface is free from algae growth, the U-value may be increased by 50 %.

5.6 Roofs with skylights

5.6.1 Concept of roof thermal transfer value (RTTV)

In the case of an air-conditioned building, the concept of Roof Thermal Transfer Value (RTTV) is applied if the roof is provided with skylight and the entire enclosure below is fully air-conditioned.

5.6.2 For roofs with skylight, in addition to the requirement of 5.5.1 the maximum recommended RTTV is 25 W/m^2.

5.6.3 The RTTV of roof is given by the following equation.

$$RTTV = \frac{(A_r \times U_r + TD_{eq}) + (A_s \times U_s \times \Delta T) + (A_s \times SC \times SF)}{A_o} \quad .....(6)$$

where,

$RTTV$ is the roof thermal transfer value (W/m^2);

A_r is the opaque roof area (m^2);

U_r is the thermal transmittance of opaque roof area (W/m^2 *K);*

TD_{eq} is the equivalent temperature difference *(K),* as from Table 10;

A_s is the skylight area (m^2);

U_s is the thermal transmittance of skylight area (W/m^2);

ΔT is the temperature difference between exterior and interior design conditions (5 K);

SC is the shading coefficient of skylight;

SF is the solar factor (W/m^2), see 5.6.5; and

A_o is the gross roof area (m^2) where $A_o = Ar + A_s$.

As with the OTTV, the roof thermal transmittance or the RTTV, where there are skylights, can also be calculated using a simple spreadsheet. For light weight roof its 0.4 w/m2K and for heavy roofs its 0.6 w/m2K. What types of construction will comply and which will not?

1. Standard concrete tiled roofs with no insulation would not comply to the standard as the U-value would typically be about 0.7 w/m2K, exceeding the requirement of 0.4 w/m2K
2. Concrete tiled roofs with 50 mm fiberglass insulation would just barely meet the requirement, and 75 mm is therefore recommended.
3. A 100mm thick concrete roof slab with 3 w/m2Kwould not meet the requirement of 0.6 w/m2K and therefore an insulation of a minimum of 50 mm of polystyrene is required to bring it to about 0.5 w/m2K. A 100 mm is therefore recommended.

Summary

1. Architects and Engineers are required to comply with MS 1525 requirements for NON-RESIDENTIAL buildings with AIR CONDITIONED AREAS LARGER THAN 4000 SM after the UBBL amendment is made.
2. Architects will have to submit OTTV & RTTV calculations to show compliance with Section 5 of MS 1525
3. With the latest computer spread sheets, testing of different options would be a simple matter of extracting data from manufacture's catalogues and imputing the basic data in the U-values spread sheets and then transferring them to the OTTV spreadsheets.
4. Solar radiation through glass windows is the greatest contributor to the OTTV typically accounting for between 70% to 85% of the overall OTTV, depending on the glazing area. The large constant of 194 already hints that this is a major factor in the overall OTTV. In order to keep the OTTV contribution for exceeding 50 w/m2, the shading coefficient is a major contributor to the overall OTTV as it can change this component by between 30% to 80% of OTTV.

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