Chapter 5 – Glazing Properties

Building Energy Efficiency Technical Guideline for Passive Design (Draft 1)

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Foreword

This document is produced as part of Component 4, Building Sector Energy Efficiency Program (BSEEP) by CK Tang (ck@gbeet.com) and Nic Chin (nc.environmentology@gmail.com).

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5.1 Introduction

In recent years, a number of local buildings in Malaysia have been built using simple single clear glazing for a 'transparent' building look, clearly unaware (or not troubled) that the use of such glazing selection increases the air-conditioning load of the building significantly causing high energy use and increased capital cost of the air-conditioning system. These buildings highlighted that there are architects that are not aware of the changes in glazing technology that allowed such transparent building to be constructed energy efficiently without compromising on the 'transparent' look of the building.

The selection of correct glazing properties can help to increase energy efficiency in the building and yet provide the 'desired look' of the building. Right glazing selection can reduce the cooling load in building, provides better comfort while allowing smaller air-conditioning system to be used, saving investment cost. In addition, selection of right glazing also influence the potential of daylight harvesting in building that will reduce electrical lights usage that saves a significant amount of energy in building, as well as providing an improved thermal comfort and visual comfort environment to the building occupants.

Finally, many architects today understood the need to have low solar heat gain coefficient (SHGC) to reduce heat gain in building and high visible light transmission (VLT) to promote daylight harvesting. However, not many understood the relationship between SHGC and VLT due to different glazing technology and mechanism used. This, among many issues with regards to glazing properties selection, is addressed in this chapter.

5.2 Key Recommendations

The most important factor to consider in this climate zone for glazing selection, in terms of energy efficiency, is the solar heat gain coefficient (SHGC). The lower the SHGC value, the better it is because it means that less solar heat would enter the building through the glazing.

Another important factor to consider in glazing selection for energy efficiency is the visible light transmission (VLT) of the glazing. The VLT of glazing will determine the amount of daylight that is possible to be harvested. In Chapter 4, it was shown that glazing with VLT below 20% is deemed too dark for daylight harvesting. In addition, higher VLT does not necessary mean more daylight harvesting. It was also shown in Chapter 4 that glazing with higher VLT values will require better daylight reflection system be in place to distribute the daylight evenly for better efficiency gain.

The ratio of VLT over SHGC provides a term called light to solar gain ratio (LSG). Single glazing **without** low-e properties has LSG values of 0.5 to 1.0 depending on the colour of the glazing. Single glazing **with** low-e properties has typical LSG values of 1.05 to 1.25. High performance, double glazing with low-e properties has typical LSG values of 1.6 to 2.0.

It is recommended not to use double glazing with LSG values less than 1.5, because the marginal cost of having double glazing with LSG value above 1.5 is relatively low once double glazing is selected to be used in the 1st place.

Recommended strategy for glazing selection

1. Choose the glazing with the colour, visible light transmission and reflectivity required for the desired architectural look for the building.
2. If daylight is being harvested, a minimum visible light transmission (VLT) of 20% is recommended. The higher the VLT, the more daylight can be harvested. However, daylight harvesting has to be done carefully to ensure that it will not cause glare discomfort and the daylight is distributed evenly. (Chapter 4)
3. Based on the colour, visible light transmission and reflectivity of the glazing, ask for these 3 options to be provide with the cost estimate and SHGC value:
    a. Single Tinted Glazing without Low-e.
    b. Single Tinted Glazing with Low-e
    c. Double Glazing with Low-e and LSG value more than 1.5
4. Use the MS1525 to estimate the OTTV value of each option. Then conduct an extra cost vs. energy reduction estimate for different OTTV options (section 5.7).
5. If reduction of glazing area is not possible, consider the use of high performance double low-e glazing to reduce SHGC values.
6. Compare the increased cost of double glazing with the option of providing external shades. (Chapter 6)
7. Finally, consider the use of internal reflective shades but be aware of the issues that need to be addressed on the use of internal shades to reduce solar heat gain. (Chapter 6)

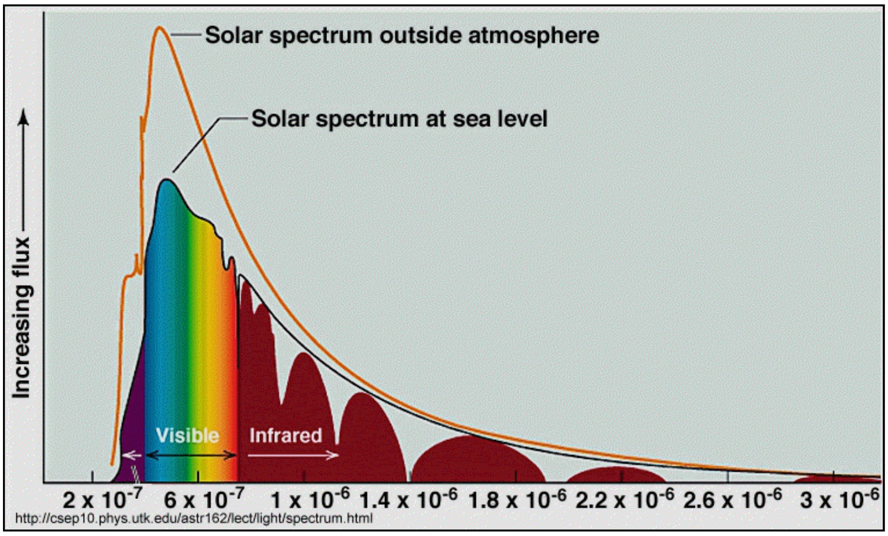
Energy Efficiency Glazing Selection in Transparent Building

To achieve a 'transparent' building look while maintaining energy efficiency, it is required to invest in glazing technology. It was observed that a few 'transparent' looking building in Klang Valley have VLT above 70%. If a typical single clear glazing is selected, the SHGC will be approximately 0.70 or higher. If a typical low-e single glazing is used, the SHGC can be approximated to be 0.61, using a light to solar gain ratio (LSG) of 1.15. However, if a high performance low-e double glazing technology is selected (with LSG of 2.0), it is possible to get a SHGC value as low as 0.35.

Finally, it is should be highlighted that the author of this document is unsure if a 'transparent' looking building can remain 'transparent' during operation. Issues such as glare discomfort, occupant's privacy, the look of unsightly offices and potential clashes of colour of internal shades (in a multi-tenanted building) needs to be addressed carefully to ensure that the building can remain 'transparent' and 'attractive' during use.

5.3 The Solar Spectrum

Solar spectrum from the sun consists of the short wave length (ultraviolet lights), medium wave length (visible light), and long wave length (infrared). The ultraviolet and infrared are invisible to our eyes and therefore, it is 'pure' heat that is not useful to buildings located in this climate zone. There exist glazing technologies that will filter out the ultraviolet and infrared from the solar spectrum and only allows visible light to pass through the glazing. These glazing technologies will enable visible light to be harvested with low heat gain in the building.



http://csep10.phys.utk.edu/astr162/lect/light/spectrum.html

Figure 5.1: Solar Spectrum Components

5.4 Glazing Terminologies

For the tropical climate, where harvesting daylight would improve the energy efficiency of the building significantly, the following terminologies are relevant:

5.4.1 *VISIBLE LIGHT TRANSMISSION (VLT)*

This is the total amount of visible light that passes through the glazing. Some part of the light would also be reflected and absorbed by the glazing. The higher the VLT, the more daylight harvesting opportunity there is. It is recommended to match the daylight harvesting strategy to the selection of VLT of the glazing. In general, glazing with VLT less than 10% looks very dull from within the building due to the lack of daylight in the building itself.

5.4.2 *SOLAR HEAT GAIN COEFFICIENT (SHGC) OR G-VALUE*

This is the total amount of solar heat that passes through the glazing. The lower the value, the better it is for tropical climate because less solar heat is transferred into the building. In single glazing, the lowest SHGC achievable is approximately 0.2 with VLT values less 10%. Due to the low VLT, it may not be desirable to use such glazing. However, in high performance low-e double glazing, it is possible to get SHGC lower than 0.15 with VLT of 25% or higher.

The term "SHGC" is relatively new and is intended to replace the term "shading coefficient (SC)." While the terms are related, the shading coefficient of glass is defined as the ratio of the solar heat gain through a given glazing as compared to that of clear, 1/8 inch single pane glass.

5.4.3 *LIGHT TO SOLAR GAIN RATIO (LSG)*

LSG is the ratio between the visible light transmissions to the solar heat gain coefficient. The higher this number is, the better it is for buildings where daylight is harvested.

$$LSG = \frac{VLT\ (\%)}{SHGC(\%)}$$

Single glazing **without** low-e properties has typical LSG values of 0.5 to 1.0.

Single glazing **with** low-e properties has typical LSG values of 1.05 to 1.3.

High performance double glazing **with** low-e properties has typical LSG values of 1.5 to 2.0.

5.4.4 U-VALUE (W/m^2K)

The U-value of a glazing is a measure of conduction heat gain through the glazing unit. However, the U-value of glazing has a comparatively small influence on the building energy consumption in tropical climate as compared to the VLT, SHGC and LSG properties of the glazing. For the tropical climate, it is recommended to select glazing based on VLT, SHGC and LSG values, while keeping the U-value as a by-product of the selection process, because, in this climate, a good glazing selection based on VLT, SHGC and LSG would typically improves the U-value of the glazing, except for normal single glazed tinted glazing. In this climate, it is not economically justifiable to select glazing based on U-values alone. However, if the selection of glazing based on VLT, SHGC and LSG gives a better U-value, then it is better for the building.

5.5 Glazing Technologies for Energy Efficiency

A good glazing technology has advantage over external shading because a good glazing will reduce solar heat gain from both direct and diffuse solar radiation, while external shading largely reduces direct radiation and has only a small influence on heat gain from diffuse radiation (Chapter 6).

Glazing technology has improved significantly over the last 10 years. These are common technologies in glazing available today to reduce energy consumptions in building:

5.5.1 SINGLE GLAZING LOW-E

These are hard coated metallic coating on surfaces of glazing that can be exposed to indoor climate. The metallic coating on the inside surface reduces the emissivity of the glazing by 50% or more, thereby reducing the heat that is radiated into the internal spaces. These glazing will provide better comfort condition to the building occupants due to its lower radiant heat and will indirectly allow the air-conditioning temperature to be raised to maintain comfort condition. It is not difficult to find single glazing low-E products with LSG between 1.0 and 1.3.

5.5.2 DOUBLE GLAZING LOW-E

These are soft coated metallic coating on the surfaces of glazing that cannot be exposed. These coatings have to be protected in between glazing. These metallic coatings on the inside surface reduces the emissivity of the glazing by 95% or more, thereby reducing the heat that is radiated to the internal spaces. It is not difficult to find double glazing low-E products with LSG between 1.6 and 2.0.

5.6 Energy Simulation

Energy simulation was conducted to derive an approximate estimate of energy and peak load reduction of reducing window area and the selection of good glazing properties for each orientation. These estimates are provided as a guide for quick design checks by architects, engineers and building owners to estimate the cost saving of implementing these energy efficiency features.

5.6.1 REDUCTION OF GLAZING AREA

Chapter 4 showed that from a purely energy efficiency point of view, glazing area should be reduced as long as it does not affect the uniformity of daylight distribution in building. A table below is provided below providing the peak cooling load and energy reduction from the reduction of glazing area in the various orientation of the building. These values are derived from an assumption that single glazing with SHGC value of 0.75 is used. Glazing with lower SHGC value is not provided in this study because the glazing area in building is normally decided without consideration of the properties of the glazing used. It is only after the design of the glazing area has been decided; the properties of the glazing would then be selected. Therefore, it is proposed to use this table below only as a reference for architects to decide to add or reduce glazing area for different facade orientation of the building.

Orientation	**North**	**South**	**East**	**West**
Energy Reduction (per year) Per Glazing Area Reduction (kWh/m2 of glazing area reduced)	88.60	81.07	136.11	101.62
*RM Reduction (per year) Per Glazing Area Reduction (RM/m2 of glazing area reduced)	31.01	28.38	47.64	35.57
**Peak Cooling Load Reduction Per Glazing Area Reduction (kW/m2 of glazing area reduced)	214.50	132.74	344.70	266.02

Table 5.6.1.1: Energy and Peak Load Impact of Reducing of Glazing Area

*A simplified energy tariff of RM 0.35 per kWh is used.

** Only applicable for buildings with glazing area distributed evenly on all orientation.

The peak cooling load reduction provided in the table above is only valid on the assumption that the building glazing areas are distributed rather evenly on all the orientation. If for example, West orientation glazing area is 200% more than the glazing area on other areas, reducing glazing area on North, South and East will not reduce peak cooling load of the building. This is because the west orientation is dominating the peak heat gain of the building.

<u>Example 1. Use of Table 5.6.1.1</u>

Base Design of East Façade as a Glazing Area of: 2,000 m²
Revised Design of East Façade has a Glazing Area of: 1,700 m²

Calculations:

East Façade Glazing Area Reduction = 2,000 m² - 1,700 m² = 300 m²
Table 5.1, East Façade: Energy Reduction of 136.11 kWh/m² of glazing reduction.
Energy Saved per year due to Reduction of Glazing Area on the East Façade:
300 m² x 136.11 kWh/m² = 40,833 kWh/year,
Providing a saving of RM 14,291.55 per year.

<u>Example 2. Use of Table 5.6.1.1</u>

Base Design of South Façade as a Glazing Area of: 1,500 m²
Revised Design of South Façade has a Glazing Area of: 1,950 m²

Calculations:

South Façade Glazing Area Addition = 1,950 m² - 1,500 m² = 450 m²
Table 5.1, South Façade: Energy Reduction of 81.07 kWh/m² of glazing reduction.
Energy Increase per year due to Addition of Glazing Area on the South Façade:
450 m² x 81.07 kWh/m² = 36,481.50 kWh/year,
Providing an increase of RM 12,768.52 per year.

5.6.2 *REDUCTION OF SOLAR HEAT GAIN COEFFICIENT (SHGC)*

The lower the value of SHGC for the window, the less heat is transferred into the building. However, in a single glazing, the lowest SHGC achievable today is approximately 0.2 and it has to be a dark glazing with low visible light transmission (VLT less than 10%). Selection of such dark glazing for a building today may make the building seems old-fashioned from the outside and not desirable on the inside due to the lack of daylight within the building. However, it is possible to find high performance double glazing with low-e that achieves SHGC of 0.15 or lower and yet has a visible light transmission (VLT) of 25% or higher. In short, it is possible to select a double glazing that is cooler (as compared to single glazing) and yet provides decent daylight harvesting opportunity for the building. It should be noted that actual performance varies between glazing manufacturers and colour selection.

A table is provided below to estimate the energy and peak load reduction of using glazing with reduced SHGC value.

Orientation	**North**	**South**	**East**	**West**
Energy Reduction (per year) Per Glazing Area Per SHGC Reduction (kWh/m2.shgc of glazing area)	115.54	100.69	150.14	130.56
*RM Reduction (per year) Per Glazing Area Reduction Per SHGC Reduction (RM/m2.shgc of glazing area reduced)	40.44	35.24	52.55	45.70
**Peak Cooling Load Reduction Per Glazing Area Per SHGC Reduction (kW/m2.shgc of glazing area)	267.86	144.14	310.24	355.82

Table 5.6.2.1 Energy and Peak Load Impact of Reducing of SHGC, in Single Glazing

*A simplified energy tariff of RM 0.35 per kWh is used.

** Only applicable for buildings with glazing area distributed evenly on all orientation.

The peak cooling load reduction provided in the table above is only achievable on the assumption that the building glazing areas are distributed rather evenly on all the orientation. If for example, West orientation glazing area is 200% more than the glazing area on other areas, reducing glazing area on North, South and East will not reduce peak cooling load of the building. This is because the west orientation is dominating the peak heat gain of the building.

Energy reduction of SHGC in double glazing is higher than single glazing (where the base building assumption is still using a single glazing) and the table below provides the savings achievable of using double glazing instead of single glazing.

Orientation	**North**	**South**	**East**	**West**
Energy Reduction (per year) Per Glazing Area Per SHGC Reduction (kW/m2.shgc of glazing area)	158.64	141.97	215.45	171.84
*RM Reduction (per year) Per Glazing Area Reduction Per SHGC Reduction (RM/m2.shgc of glazing area reduced)	55.53	49.69	75.41	60.14
**Peak Cooling Load Reduction Per Glazing Area Per SHGC Reduction (kW/m2.shgc of glazing area)	437.19	294.23	562.83	478.55

Table 5.6.2.2: Energy and Peak Load Impact of Reducing of SHGC, in Double Glazing

*A simplified energy tariff of RM 0.35 per kWh is used.

** Only applicable for buildings with glazing area distributed evenly on all orientation.

Example 3. Use of Table 5.6.2.1 & Table 5.6.2.2

Base Design.
North Façade: 1,500 m², Single Glazing, SHGC 0.75
East Façade: 1,200 m², Single Glazing, SHGC 0.75

Revised Design.
North Façade: 1,500 m², Single Glazing, SHGC 0.40, Additional Cost: RM 30/m² of glazing area.
East Façade: 1,200 m², Double Glazing, SHGC 0.20, Additional Cost: RM 250/m² of glazing area.

Calculations:

North Façade:
SHGC Reduction = 0.75 – 0.40 = 0.35
Energy Reduction Table 5.2 for single glazing: 115.54 kWh/m².shgc
Energy Reduction per Year: 115.54 kWh/m².shgc x 0.35 x 1,500 m² = 60,658.50 kWh/year
Providing a saving of RM 21,230.48/year
Total Additional Cost (RM): RM 30/m² x 1,500 m² = RM 45,000
Simple Payback = RM 45,000 / RM 21,230.48 = 2.1 years.

East Façade:
SHGC Reduction = 0.75 – 0.20 = 0.55
Energy Reduction Table 5.3 for double glazing: 215.45 kWh/m².shgc
Energy Reduction per Year: 215.45 kWh/m².shgc x 0.55 x 1,200 m² = 142,197 kWh/year
Providing a saving of RM 49,768.95/year
Total Additional Cost (RM): RM 250/m² x 1,200 m² = RM 300,000
Simple Payback = RM 300,000 / RM 49,768.95 = 6.0 years.

5.6.3 *Reduction of U-value in Glazing*

Reduction of glazing U-value by switching from single glazing to double glazing will also reduce the SHGC slightly because 2 panes of glass is now used instead of 1. The additional pane of glass will reflect and absorb some of the solar radiation and is considered in this study. The result of this study shows that energy reduction due to the U-value reduction in glazing is significantly small as compared to the reduction of glazing area and SHGC provided by Tables 5.1 to 5.3.

Orientation	**All**
Energy Reduction (per year) Per Glazing Area Per U-value Reduction (kWh/m2.u-value reduction)	4.24
*RM Reduction (per year) Per Glazing Area Reduction Per SHGC Reduction (RM/m2.u-value reduction)	1.48
**Peak Cooling Load Reduction Per Glazing Area Per U-value Reduction (kW/m2.u-value reduction)	13.93

Table 5.6.3.1: Energy and Peak Load Impact of Reducing U-value in Glazing

*A simplified energy tariff of RM 0.35 per kWh is used.

** Only applicable for buildings with glazing area distributed evenly on all orientation.

5.7 The MS1525 OTTV

The Malaysian Standard available from Sirim, MS1525, provides a method to calculate the Overall Thermal Transmission Value (OTTV) of a building fabric. The original form of OTTV was developed for

ASHRAE Standard 90 in 1975[1] and refined again in 1980[2]. The OTTV constants were derived from energy simulation studies, where in the 1970s, is only in the domain of universities and research centers. In summary, the OTTV provided a mean of estimating the energy load of a building fabric system without requiring the use of energy simulation tools, enabling it to be used by any architects and engineers to make estimates of average cooling load in building due to building fabric choices.

The OTTV is defined by ASHRAE as the average chiller cooling load gained due to the choice of building fabric (excluding the roof) based on the condition outside (weather) and a 'typical' condition inside an office building. Today, ASHRAE 90 has since discarded OTTV, in favor of energy simulation. This is because energy simulation is now accessible by almost all architects and engineers as compared to the 1980s. Moreover, the OTTV was found to be inaccurate for climates having different seasons (colder winter and warmer summer) or different air-conditioning hours.[3]

Despite these disadvantages, the OTTV do offers a simple solution to give reasonably good estimates of heat gained into the building due to solar radiation through the window, conduction through the wall and conduction through the window. The OTTV formula in MS1525 (2007) is reproduced below as a reference.

$$\text{OTTVi}\ (\text{W/m}^2) = 15\,\alpha\,(1 - \text{WWR})\,U_w + 6\,(\text{WWR})\,U_f + (194 \text{ x CF x WWR x SC})$$

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 MS1525 (2007) Table 4; and

SC is the shading coefficient of the fenestration system.

Orientation	CF
North	0.90
Northeast	1.09
East	1.23
Southeast	1.13
South	0.92
Southwest	0.90
West	0.94
Northwest	0.90

Table 5.7.1: MS1525, Table 4. Solar correction factors

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[1] ASHRAE Standard 90 ProjectCommittee. 'Energy Conservationin New Building Design. ASHRAE Standard: 90-1975." AmericanSocietyof Heating,Refrigerationand Air ConditioningEngineers,Inc., Atlanta,GA, 1975

[2] ASHRAE Standard 90 ProjectCommittee. 'Energy Conservation in New Building Design. ASHRAE Standard: 90A-1980, 90B-1975, 90C-1977." American Society of Heating, Refrigeration and Air ConditioningEngineers,Inc., Atlanta,GA, 1980.

[3] S. Chirarattananon and J. Taveekun. 2004. "An OTTV-based energy estimation model for commercial buildings in Thailand. Energy and Building, Vol. 36, Issue 7, July, pp 680-689.

5.7.1 REPLACEMENT OF SC WITH SHGC IN OTTV

The term shading coefficient or SC was proposed by the scientific communities in recent years to be discarded in favor of SHGC, solar heat gain coefficient, because the definition of SC is not sufficiently specific enough for industry use, while the definition of SHGC is simple and definite. In general, SHGC can be approximated from SC using this equation: SHGC = 0.87 x SC. Replacing the SC with SHGC in the OTTVi equation in MS1525 will yield the new equation below.

$$\mathrm{OTTVi}\ (\mathrm{W/m^2}) = 15\,\alpha\,(1 - \mathrm{WWR})\,U_w + 6\,(\mathrm{WWR})\,U_f + (223 \times \mathrm{CF} \times \mathrm{WWR} \times \mathrm{SHGC})$$

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 ($\mathrm{W/m^2\,K}$);
U_f is the thermal transmittance of fenestration system ($\mathrm{W/m^2\,K}$);
CF is the solar correction factor; as in MS1525 (2007) Table 4; and
$SHGC$ is the solar heat gain coefficient of the fenestration system.

5.7.2 USING OTTV TO ESTIMATE ENERGY REDUCTION

The OTTV equation itself can be used to estimate annual energy reduction in office building due to the differences in façade design. The definition of OTTV by ASHRAE 90, as the average chiller cooling load of a typical office building for the entire year is the exact explanation on how OTTV can be used to estimate cooling load reduction.

In summary, the energy saved due to cooling load reduction (or addition) of a building in Malaysia due to change in OTTV can be estimated using this equation below:

$$ER = \frac{(OTTV_1 - OTTV_2)\,A_w}{SCOP\ x\ 1000}\ x\ H_{ac}$$

Where,

ER is the energy reduction per year (kWh/year)
$OTTV_1$ is the computed OTTV based on option 1 ($\mathrm{W/m^2}$)
$OTTV_2$ is the computed OTTV based on option 2 ($\mathrm{W/m^2}$)
A_w is the area of walls (inclusive of glazing areas) ($\mathrm{m^2}$)
SCOP is the Air-Conditioning System Coefficient of Performance
H_{ac} is the Hours of air-conditioning per year (approximately 2700 hours)

This equation above is valid for buildings using Constant Air Volume (CAV) system and is a good approximation for buildings using Variable Air Volume (VAV) system. The SCOP can be approximated using these recommended values: 2.8 for split-unit air-conditioning system, 4.0 for a centrifugal based chill water system. More accurate SCOP can be approximated by your air-conditioning system designer based on the equipment used.

5.7.2.1 Correct Solar Factor Used in MS1525?

A study made in 2006, showed that the average solar factor of the test reference year weather data is significantly lower than the average solar factor used by the MS1525 (2007) OTTV formulation, 160 W/m² vs. 194 W/m² respectively.[4] These differences are due to the fact that the original MS1525 OTTV solar factor was derived from a couple of days measurement made on vertical surface in Penang in the 1980s, while the Test Reference Year (TRY) is based on hourly analysis of solar radiation in Subang (Chapter 2).

In addition, it was presented by the Malaysian Building Integrated PhotoVoltaic (MBIPV) project that Penang received a higher yearly solar irradiance (~1850 kWh/m²) (approximately 23% more) than the Klang Valley (~1500 kWh/m²) where Subang is located.[5] Meanwhile, the measured solar factor of 194 W/m² in Penang is 21% higher than the solar factor of 160 W/m² in Subang derived from the test reference year weather data. In summary, the information provided by MBIPV project seems to indicate that both solar factor are correct for its own location. However, further studies are recommended to validate these observations.

The correct solar factor will yield the correct computation of solar heat gain in building. It is highly recommended that further research should be conducted to establish the correct solar factors to be used in the MS1525.

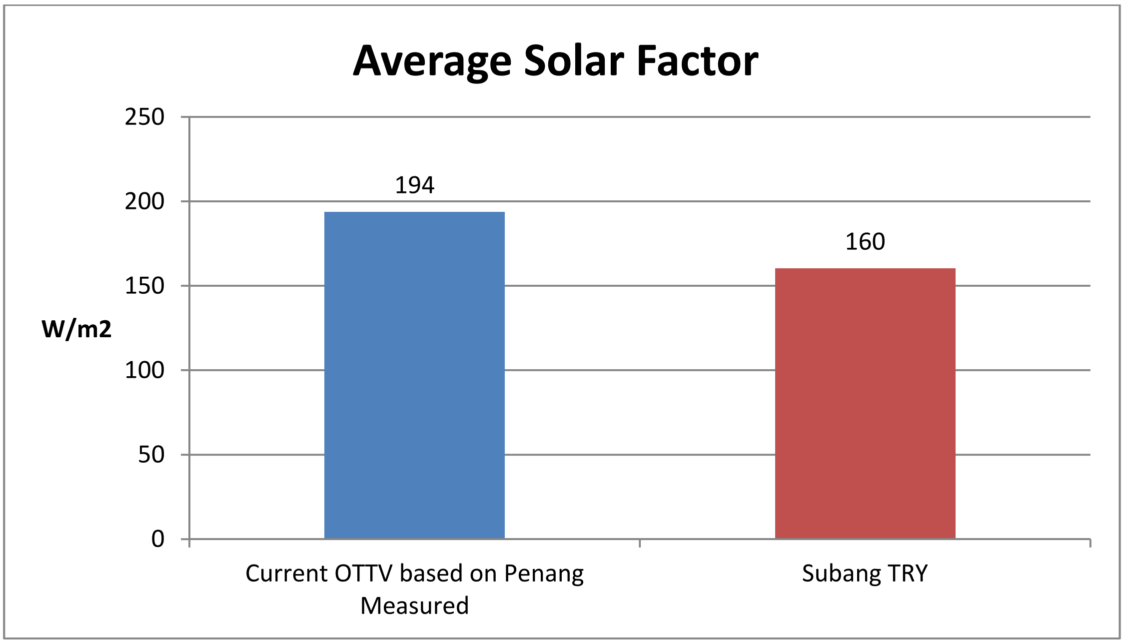

Chart 5.7.2.1.1: Average Solar Factor[6]

________________________________End of Chapter 5______________________________________

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[4] CK Tang, Dr. K.S. Kannan, Ole Blashev Olesen, Steve A. Lojuntin, Dr. BG Yeoh, A Review of the OTTV Formulation in the Support of Energy Efficiency Code for Non-domestic building, MS 1525, May 2006, Prepared for the Danida program in Malaysia (2004-2006).

[5] Ir. Ahmad Hadri Haris, MBIPV Project: Catalyzing Local PV Market, Finance & Investment Forum on PV Technology, 17th March 2008, Kuala Lumpur Tower

[6] CK Tang, Dr. K.S. Kannan, Ole Blashev Olesen, Steve A. Lojuntin, Dr. BG Yeoh, A Review of the OTTV Formulation in the Support of Energy Efficiency Code for Non-domestic building, MS 1525, May 2006, Prepared for the Danida program in Malaysia (2004-2006).