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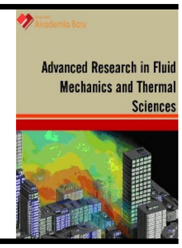

Energy Efficiency through Building Envelope in Malaysia and Singapore

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ABSTRACT

The optimisation of fossil fuel consumption for generating electricity for building cooling is among the objectives set by most of the countries in the world. Currently, the American and European standards are among the most referred standards in the world for optimising heat transfer through the building envelope. However both standards do not reflect climate specifications of some countries such as those located in the humid tropics. The divergence in the approaches adopted by several Asian countries in minimising the heat transfer through the building envelope added another complexity to the topic. Other complexities are the divergence of European and American standards and the additional issue about the lack of validated weather data (TRY) in the humid tropics such as the case of Malaysia and Singapore. Those and other relevant issues on energy efficiency through the building envelope were addressed in the present article. Additionally a worked example and Excel sheet formulas were developed while considering Malaysian and Singaporean codes. Some recommendations were also suggested in the present article when deemed necessary.

1. Introduction

It is a widely known fact that the climate is currently changing due to global warming. This has affected negatively the earth's climate. Metropolitan cities are further exposed to the urban heat island effect as a result of their rapid growth and unsustainable modern style of living [1-3]. Generally, an urban heat island is reflected by an increase of temperature in a city compared to adjacent rural locations. Minimising the energy consumption and carbon dioxide emissions are vital when considering building thermal design for occupants' thermal comfort [4]. This is because any change in the outdoor air temperature will influence the indoor air temperature. This in turn will affect negatively the environment, productivity, and physical and mental health of people. Productivity refers to business-oriented returns. It may also include other diverse task performances. Furthermore, an urban heat island will also increase peaks in electricity demand [5].

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Air conditioning is widely used for the operation of commercial buildings in the world. Malaysia and Singapore are no exception. Central air-conditioning systems require great electrical costs owing to the power consumption of the compressor [30]. This may explain further the recent growing interest in building sectors for natural ventilation [31].

Currently, there are national standards all over the world for building thermal efficiency. This is by controlling heat gain through the building's envelope. The building envelope refers to the part of the construction that physically separates the exterior from the interior environment. It is also known as the building enclosure. Thus, careful consideration of heat gain through the enclosure is important for substantial energy savings while considering occupant thermal comfort.

In the building regulations, the overall thermal transfer value (OTTV) has been adopted in the Malaysian standard since 2001. The OTTV measures the average heat gain through the building envelope. The OTTV is also considered as an index for comparing the thermal performance of several buildings [7]. The OTTV applies only to air-conditioned buildings for the purpose of minimising the cooling load. It was reported that the accuracy of the OTTV depends on the latitude of the location [8]. For the Malaysian case, the first OTTV formula was developed in 1992 by Deringer and Busch as described in reference [9]. The OTTV consists of three major components. These are conduction through opaque walls, conduction through window glass, and solar radiation through window glass [10]. Solar radiation through window glass is critical in minimising energy consumption. This is because most of the energy needed for cooling purposes in a building is due to solar heat gain through windows [4]. Heat gain through windows in turn affects drastically the indoor thermal comfort. Huizenga *et al.,* [11] mentioned that the influence of overall comfort is by window component. Window component refers to the frame, edge, and centre of the glass. Tinker and Baharun [12] stated that the perspective of energy efficiency tends to be neglected in many buildings in Malaysia. This is the case of many locations all over the world. Figure 1 shows two examples of large glazed facades in Kota Kinabalu area. Such type of buildings can transmit a considerable amount of heat from outside into the building.

Fig. 1. Suria Sabah shopping mall and Yayasan Sabah, Kota Kinabalu

Chaiyapinunt and Khamporn [13] added that when glass windows are installed in common building envelopes, the absorbed solar radiation will increase the glass temperature. This in turn reradiates the heat into the room from the higher glass surface temperature to the lower indoor air temperature via long-wave radiation.

There are several issues related to window thermal performance that need to be addressed under the current Malaysian standard [10]. For instance, it is not clearly stated in the standard if the whole window assembly should be considered when estimating the OTTV. The whole window assembly refers to the frame, seals and any spacers which have an effect on heat gain through the building envelope. This is in addition to the glass. This is probably the case of many Asian countries using the OTTV concept in their standards. Saša *et al.,* [4] emphasised the importance of the calculation of the heat transfer via conduction through windows. This is by considering the window frames, window glass, chamber fill between the glass panes, and standard window dimensions. The same authors mentioned that in order to select window type both structural and energy requirements should be satisfied.

The National Fenestration Rating Council (NFRC) also considers the solar heat gain coefficient for the whole window with the frame. The centre of the glass without frame is sometimes used to describe the effect of the glass alone. It was reported that the solar heat gain coefficient for the whole window with the frame is lower than the solar heat gain coefficient for the glass only. Chou [14] stated that the frame of a total fenestration area is around 10% to 30%. He also mentioned that thermal breaks are highly effective in reducing heat transfer through fenestrations with aluminium frames. The author reported very important information on the impact of building envelope design on energy efficiency and thermal comfort in the tropics. Singapore was the case study under consideration. Further investigations in the same direction in Malaysia are highly recommended for any possible further update of the MS 1525 standard in the near future.

Another issue worth addressing is about the international standards in rating the thermal performance of windows. The main known organisation for rating the thermal performance of windows in North America is the National Fenestration Rating Council (NFRC). Rating the thermal performance of windows in Europe is based on ISO and EN standards. Hanam *et al.,* [15] explained that the NFRC U-values are modelled at an outdoor temperature of -18°C. Such low temperature as explained by the authors reflects the average winter temperature in several North American locations. Alternatively, the ISO U-values are rated at an outdoor temperature of 0°C. In fact, the authors mentioned that higher outdoor air temperatures will result in lower window U-values. Therefore, they suggested for the industry to add subscripts for NFRC and ISO U-values to distinguish European from North American U-values. This is because the U-values are climate-specific. This will be certainly suggested for the Malaysian standard and for other countries. This probably will help in differentiating between both products so that the impact of such rating procedure on energy consumption under the Malaysian climate will be addressed. This is also important for developing or updating Malaysian green building indexes.

It is widely known that the selection of glass is very important to OTTV and people's thermal comfort. In Honolulu, the Hawaiian commercial building guidelines for energy efficiency recommended the use of low-emissivity glasses such as blue or green tints with low solar heat gain coefficient and high visible light transmittance. Visible transmittance refers to the fraction of the visible spectrum of sunlight allowed to access through a window, whereas the solar heat gain coefficient refers to the fraction of incident solar radiation allowed to access through a window. It includes both directly transmitted and absorbed solar radiation inside the building. Additionally, the guidelines stated clearly that in Hawaii, high solar heat gain coefficient is more important than low U-factor [16]. Honolulu experiences a tropical hot climate with little variation of air temperatures throughout the months. Therefore, some of their recommendations can be always considered for other tropical humid locations all over the world.

2. Heat Gain through Building Envelope

There are several versions of OTTV which are currently used in various Asian countries. This has to be expected due to the differences in their climates and to the adopted procedures in estimating the OTTV. For instance, Singapore, Malaysia, Thailand, Philippines, Jamaica and Hong Kong have different approaches in estimating the OTTV in their standards. In fact, the OTTV used in the Singaporean code is named ETTV. It refers to envelope thermal performance value in commercial buildings. RETV is equivalent to OTTV for residential buildings. The ETTV is similar to the OTTV concept. In the Malaysian standard, the OTTV procedure is only applicable for commercial buildings. The ETTV is one of the prerequisite requirements in both Green Mark and GreenRE in Singapore [17]. The situation is similar in Malaysia.

The calculation of the OTTV probably can be traced back to ASHRAE Standard 90-75. It was developed so that the OTTV of an air-conditioned building should not exceed 50 W/m^2. However, later it was found that OTTV underestimates the solar radiation gain through the fenestration system. Additionally, the simultaneous effect of the building envelope, internal heat gains and equipment efficiency are ignored in the OTTV. This probably affected the thermal performance of a building. The reader may refer to [18, 19] for further information. In fact, the OTTV method has been discarded in the US from the ASHRAE Standard 90.1. This is because the OTTV lacks accuracy for a building exposed to seasonal variation [20]. This probably is not the case in the humid tropics. This is because the climate is mostly similar all year round. However, probably the major issue with the OTTV in the humid tropics is the ignorance of internal load during non-air-conditioned hours. The OTTV method was replaced by ASHRAE 90.1-1989 in the U.S. [21]. Consequently, selected norms were established to regulate the percentage of window-to-wall ratio, the thermal transmittance separating conditioned and unconditioned spaces of envelope elements, and the thermal resistances of slabs and walls below grade [18].

Many countries are now moving towards energy performance criteria. This is by providing to designers a greater flexibility while considering the effect of local hourly climatic data on the performance of a building. This is because energy simulation is now available to engineers and architects for the assessment [20]. Such investigations are also used to update local and international standards by considering other omitted factors affecting building thermal performance. This is important for any location to maintain its economic competitiveness in the international market.

3. Malaysian OTTV vs. Singaporean ETTV

Singapore was the first country to implement regulatory control on ETTV since 1979 [8]. The initial effort for both OTTV or ETTV for the Singaporean case may probably traced back to the work of Deringer and Busch (1992) in establishing the ASEAN-USAID Buildings Energy Conservation Project [8]. Their study was concerned with commercial buildings for potential energy savings. The first phase of the project was initiated in 1982 with collaboration by U.S. researchers at Lawrence Berkeley Laboratory (LBL) and the Singaporean government. The initiation of a second phase was in 1985. The ASEAN-USAID project included Singapore, Malaysia, Indonesia and other ASEAN nations [8]. The general form of the OTTV equation is

$$OTTV = A \times UW \times (1 - WWR) + B \times UF \times WWR + C \times SF \times SC \times WWR \tag{1}$$

where
$A = \Delta T_{eq}$ is equivalent indoor-outdoor temperature difference for the opaque wall (°C),

$B = \Delta T$ is indoor-outdoor temperature difference for the fenestration (°C),
C is solar factor (°C),
UW is U-value of the opaque wall under a standardised condition ($Wm^{-2}K^{-1}$),
WWR is window-to-exterior wall ratio,
UF is U-value of the fenestration ($Wm^{-2}K^{-1}$),
SF is solar orientation factor (Wm^{-2}), and
SC is shading coefficient.

The SC can be approximated from the solar heat gain coefficient ($SHGC$) using equation (2). The lower a window's solar heat gain coefficient, the less solar heat it transmits.

$$SC = SHGC/0.87 \tag{2}$$

Window-to-wall ratio is defined by:

$$WWR = \frac{\mathrm{A_f}}{\mathrm{A_0}} \tag{3}$$

where
A_F = fenestration area (glass) (m^2),
A_w = opaque wall area (m^2), and
A_0 = gross area of exterior wall (m^2).

$$A_0 = A_f + \mathrm{A_w} \tag{4}$$

The shading coefficient of a shading system is the product of the shading coefficients of its subsystems,

$$SC = SC_1 \times SC_2 \tag{5}$$

where
SC is the effective shading coefficient of the fenestration system,
SC_1 is the shading coefficient of subsystem 1 (e.g. glass), and
SC_2 is the shading coefficient of subsystem 2 (e.g. external shading devices).

It is probably important to mention that that the shading coefficient in Malaysian standards and publications is 194 W/m^2 (Table 1). However, the situation is slightly different for the Singaporean case (Table 2). Tang and Chin [20] reported that 222 W/m^2 was the initial suggested value for the solar factor for the Malaysian OTTV. However, according to the same authors, it was modified to 194 W/m^2 due to the conventional use of the shading coefficient instead of the solar heat gain coefficient in the 1980s [20]. It is also important to report that the solar absorption coefficient of the external wall (α) was also introduced probably for the first time by Deringer and Busch [8] for the estimation of the OTTV. The authors clearly stated that solar absorption coefficient affected the overall OTTV for the Malaysian case. The solar absorption coefficient of the external wall was totally ignored for the Singaporean case study. However, no justification was made by the authors about the motivation in the exclusion of this coefficient. In fact, the authors used different approaches in estimating the overall OTTV for the Asian locations. This was made probably for the purpose of investigating various OTTV approaches in those locations. It could be also due to time constraint and for other known and unknown reasons. Known reasons refer to what was clearly stated by the authors. Therefore, different OTTV formulas were suggested. It is necessary to report that the authors reported that the variation of solar absorptivity from α = 0.2 to 0.8 affected the chiller load by 8% to 9% under the Malaysian scenario. Table 1 provides the OTTV methods for walls and fenestration in Malaysia from various references.

Table 1
OTTV for walls and fenestration in Malaysia (3.14° N, 101.69° E)

Year	Walls (a) (°C)	Fenestration (b) (°C)	Solar factor (c) (Wm^{-2})	Orientation coefficient CF (SF)	Equation	Reference
1987*	20.3 α	1.5	194		(6)	[8]
1987*	19.1 α	/**	194		(7)	[8]
2001	19.1 α	/**	194	N: 0.83 E: 1.15 S: 0.85 W: 1.14	(8)	[22]
2007	15 α	6	194	N: 0.90 E: 1.23 S: 0.92 W: 0.94	(9)	[23]
2014	15 α $\boldsymbol{\alpha < 0.4}$ Colour Light $\boldsymbol{\alpha = 0.4 - 0.7}$ Colour Medium $\boldsymbol{\alpha > 0.7}$ Colour Dark	6	194	N: 0.90 E: 1.23 S: 0.92 W: 0.94	(10)	[10]

*Year refers to the date of analysis.
/** It was suggested to ignore this term from the equation. This is because there was little loss of accuracy according to the authors.

It is necessary to report that for the Malaysian case study, Deringer and Busch [8] used Penang climatic data for the development of the OTTV. Unfortunately, the data were not available on hourly basis. In fact, it was reported that the measured 1979 solar data from nearby Singapore were merged with the other weather data from Kuala Lumpur to create a weather file for DOE-2. Deringer and Busch also reported that standard procedures used for the hourly calculation were from 8 a.m. to 6 p.m. of the mean solar factor throughout the year. Interestingly, Penang and Kota Kinabalu have almost similar global solar radiation and other climatic factors [24]. Both states are located in Malaysia. It was reported that the Malaysian Building Integrated PhotoVoltaic (MBIPV) project found that Penang receives nearly 23% more solar radiation than the Klang Valley, Subang [20].

After the OTTV development, a Test Reference Year (TRY) was created by Reimann [25] by using Subang weather data from 1975 to 1995. Due to the lack of direct and diffuse solar radiation, the author used the available global solar radiation to estimate the direct and diffuse solar radiation. The author stated clearly that the results were not validated due to time limitations. For instance, the author explained that the weather data were not verified by experienced weathermen. The author also did not validate Erbs' radiation model. Tang and Chin [20] reported that the average solar factor of the Test Reference Year (TRY) weather data was significantly lower than the average solar factor used by the OTTV formulation in the MS 1525 [23]. It was 160 W/m^2 versus 194 W/m^2.

A close observation in Table 1 also revealed that since 2007, the orientation coefficient for East in MS 1525 was higher than that for West. It was attributed to the diffuse solar radiation in Kuala Lumpur which was probably higher in afternoons. However, this requires careful interpretation of the results. This is because the ETTV for Singapore had the highest diffuse radiation in percentage as compared to other Asian countries [8]. The orientation coefficient for West is higher than for East in the Singaporean code [26].

Chuah and Lee [27] mentioned that the ratio of diffuse to global solar radiation is higher during the early morning and late afternoon before sunset than around noon. Further studies are recommended to be carried out so that further updates will be made to the OTTV when necessary. It is probably important to mention that Chou [14] reported that Singapore is compiling Typical Meteorological Year weather. This is because their investigations in Singapore were only made based on a dated weather file. It is worthwhile to report that Harimi *et al.,* [24] developed a procedure for the prediction of diffuse solar radiation for Kota Kinabalu. The authors observed that there are many similarities between Penang and Kota Kinabalu climates. Additionally, the exterior vertical daylight for the humid tropic Kota Kinabalu city in East Malaysia was estimated [28]. Therefore, it is recommended to be used for the Kota Kinabau case given the lack of Test Reference Year (TRY) in Kota Kinabalu.

It is also probably important to mention that the solar factor for the Singaporean case was the lowest (130 W/m^2). It was subjected to an increase of about 62% in 2004 [26]. The reader may refer to Table 2. Unfortunately, little is available to us about the relevant reasons for such increase.

Another important issue which needs to be addressed is about the lack of information for the development of prototypical buildings for Malaysia. Deringer and Busch [8] explained that a “reference” building approach was used during the development of OTTV for the Malaysian case. It was made by using the Singaporean reference building but professional judgment was also considered relevant to contemporary construction practices in Malaysia. Finally, it is probably important to mention that not all the suggested OTTV equations by Deringer and Busch [8] were reported in Table 1 and 2.

Table 2
OTTV/ETTV for walls and fenestration in Singapore (1.35° N, 103.82° E)

Year	Walls (a) (°C)	Fenestration (b) (°C)	Solar factor (c) (Wm^{-2})	Orientation coefficient CF (SF)	Equation	Reference
1979	10 to 15 (**10**)	8.8	130**	N: 0.72 E: 1.25 S: 1.02 W: 1.25	(11)	[8]
1989	11	4.8	230	NA	(12)	[8]
2004	12	3.4	211	N: 0.8 E: 1.13 S: 0.83 W: 1.23	(13)	[26]
2017	11.88 ≅ 11.9	6.72 ≅ 6.7	210.92 ≅ 211	NA	(14)	[14]**

* This is Singapore OTTV.
** Revised ETTV by Chou [14].

4. Worked Example

Finally, a worked example was developed using an Excel sheet for the OTTV calculation. ETTV was also considered for comparison between both codes for illustration purposes. The developed Excel sheet will be made available to all researchers via Researchgate. The OTTV Excel sheet was initially developed by referring to MS 1525:2014 [10] and [29]. The differences between MS 1525:2014 [10] and SBCA:2004 [26] and the revised ETTV by Chou [14] were also considered. The ETTV developed by [14] takes into account window systems that incorporate thermal breaks. The differences in the OTTV or ETTV calculations in the present illustration are only in estimating the coefficients A, B, C, CF (or SF) as in Table 1 and 2.

For the worked example, the windows are assumed to be fully exposed to the sun. This is probably the worst possible scenario in the humid tropics. The specifications of the building and window characteristics are listed in Tables 3 and 4. Window characteristics were selected from [14]. Building characteristics were selected from [29]. Initially, the OTTV calculation was prepared following strictly the procedure used in [10]. After validation of the calculation procedure, the required input data were considered. Additionally, the OTTV equation was modified for the ETTV and when deemed necessary.

Table 3
Specifications of the building characteristics

Orientation	Wall Area (m^2)	Window Area (m^2)	Solar Absorption* (α-wall)	
			Case 1	Case 2
North	820.80	525.31	0.15	1
East	944.28	576.01	0.15	1
South	820.80	508.90	0.15	1
West	944.28	576.01	0.15	1

*Solar absorption for wall is only required and used in the estimation of OTTV.

Table 4
Specifications of the windows characteristics

	Thermally Broken Window	Non-Thermally Broken Window
Centre of glass, Ucg-value	1.159 W/m^2K	1.159 W/m^2K
Frame, Ufr-value	3.165 W/m^2K	6.932 W/m^2K
Edge, Ueg-value	1.846 W/m^2K	2.769 W/m^2K
Overall Ut-value	2.058 W/m^2K	3.932 W/m^2K
(Ucg/Ut)%	77%	240%
SHGC = 0.87 × SC	0.149	0.162
SC	0.171	0.186

The relevant equations used in the calculation with the obtained results are listed in Table 5. Little differences were found by using a non-thermally broken window with the OTTV as in [10] and by using a non-thermally broken window as in [14]. This probably occurred because the ETTV ignores the effect of solar absorptance of the wall. It is important to mention that for the OTTV calculation, it was assumed that all walls were light coloured. However, when the OTTV was recalculated with the coefficient of solar absorptance equal to 1, the effect of thermally broken window versus non-thermally broken window was apparent (Table 5). The obtained results revealed the importance of taking into account the effect of solar absorptance of the wall in the OTTV calculation.

Table 5
Estimated OTTV/ETTV using various methods

Description	Equation	**Results*** W/m^2	(R_i/ R_1)
OTTV of Non-Thermally Broken Window with α-wall = 0.15	(10)	R_1 = 39.3	1.00
OTTV of Thermally Broken Window		R_2 = 30.5	0.78
OTTV of Non- Thermally Broken Window with α-wall = 1		R_3 = 52.0	**1.32**
ETTV of Non-Thermally Broken Window	(13)	R_4 = 44.77	1.14
ETTV of Thermally Broken Window		R_5 = 38.85	0.99
Revised ETTV of Thermally Broken Window	(14)	R_7 = 42.96	1.09

Obtained **Results*** from TTV or ETTV equations

5. Conclusions

In the present study, some observations on energy efficiency through the building envelope in Malaysia and Singapore were made. In Malaysia, the OTTV applies only to air-conditioned buildings for commercial buildings. Therefore, it is recommended that a different version of OTTV should be developed for residential buildings.

In the estimation of OTTV, it was recommended that the whole window assembly should be considered when estimating the OTTV and not just the glass specification.

It was observed that different methods are used for rating the thermal performance of windows in North America and in Europe. Therefore, the rating of the thermal performance of windows is recommended to be documented so that it can be always traced back after completing the construction.

The ignorance of solar absorptance in the ETTV calculation probably overestimates the overall envelope thermal performance of commercial buildings in Singapore. Further investigations about the methods used in several standards from various countries in the world are recommended. This is for the selection of the best approach in the assessment of building thermal performance while taking into account the climate of the location and other relevant local factors.

The development and the validation a Test Reference Year (TRY) for both Malaysia and Singapore are currently of prime importance and therefore are highly recommended. It is also recommended that the TRY should be developed for each state in Malaysia. Another alternative is the development of few TRYs via climate zones. This is by grouping several locations having similar climatic data so that only few validated TRYs will be developed for the country.

References

[1] Priyadarsini, R., and N. H. Wong. "An investigation of the urban heat island of Singapore." In *41st Annual Conference of the Architectural Science Association ANZAScA 2007 at Deakin University*, 191–198. 2007.

[2] Fujibe, Fumiaki. "Urban warming in Japanese cities and its relation to climate change monitoring." *International Journal of Climatology* 31, no. 2 (2011): 162–173.

[3] Elsayed, Ilham S. M. "Mitigation of the urban heat island of the city of Kuala Lumpur, Malaysia." *Middle East Journal of Scientific Research* 11, no. 11 (2012): 1602–1613.

[4] Kalinović, Saša M., Jelena M. Djoković, and Ružica R. Nikolić. "Influence of windows geometrical parameters on calculations of the Heat conduction coefficient." *Procedia Engineering* 192 (2017): 404–409.

[5] N. Kamarulzaman, A. A. Saleh, S. Z. Hashim, H. Hashim, and A. A. Abdul-Ghani. "An overview of the influence of physical office environments towards employee." *Procedia Engineering* 20 (2011): 262–268.

[6] Chan A. L. S. and T. T. Chow. "Evaluation of Overall Thermal Transfer Value (OTTV) for commercial buildings constructed with green roof." *Applied Energy* 107 (2013) 10–24.

[7] Hui, Sam C. M. "Overall thermal transfer value (OTTV): how to improve its control in Hong Kong." In *Proceedings of the One-day Symposium on Building, Energy and Environment, Shangri-La Hotel, Kowloon, Hong Kong, HKIE BS Division/CIBSE/ASHRAE/PolyU,* 12-1 to 12-11, 1997.
[8] Deringer J. J. and Busch, J.F. (1992). "ASEAN-USAID Buildings Energy Conservation Project. Final Report. Volume I: Energy Standards." Lawrence Berkeley Laboratory, LBL-32380, 1992.
[9] Kannan K. S. "Development of an energy rating system for office buildings." In *Conference on Sustainable Building South East Asia, Malaysia*, 2007.
[10] Malaysian Standard MS 1525:2014. Energy efficiency and use of renewable energy for non-residential buildings. Code of practice. 2014.
[11] Huizenga, Charlie, Hui Zhang, Pieter Mattelaer, Tiefeng Yu, Edward Arens, and Peter Lyons. "Window performance for human thermal comfort. Final report to the National Fenestration Rating Council." Center for the Built Environment, 2006.
[12] Tinker, John and Azhaili Baharun "Improving the thermal performance of building envelopes—retrofit possibilities using dynamic thermal models." In *International Conference on Construction Technology (CONTEC), Kota Kinabalu,* 2001.
[13] Chaiyapinunt, Somsak and Nopparat Khamporn. "Selecting glass window with film for buildings in a hot climate". *Engineering Journal* 13, no. 1 (2009): 29–42.
[14] Chou S.K. (2017). Singapore. "Impact of building envelope design on energy efficiency and thermal comfort in the tropics. Update on collaboration project of NUS, Technoform and BCA." National University of Singapore, 2017
[15] Brittany Hanam. Al Jaugelis, and Graham Finch. "Energy performance of windows: Navigating North American and European window Standards." In *14th Canadian Conference on Building Science and Technology*, 1–10, 2014.
[16] Eley Associates (aka Architectural Energy Corporation). *Hawaii commercial building guidelines for energy efficiency.* Energy, Resources & Technology Division, Dept. of Business, Economic Development and Tourism, State of Hawaii, Honolulu, 2004.
[17] Seghier, Taki Eddine, Yaik-Wah Lim, Mohd Hamdan Ahmad, and Samuel Opeyemi Williams. "Building envelope thermal performance assessment using visual programming and BIM, based on ETTV requirement of Green Mark and GreenRE." *International Journal of Built Environment and Sustainability* 4, no. 3, (2017) 227–235.
[18] Oraee Namzadi, Mehran and Mark B. Luther. "The next step in energy rating: The international ETTV method vs. BCA Section-J glazing calculator." In R.H. Crawford and A. Stephan (eds.), *Living and Learning: Research for Better Built Environment: 49th International Conference of the Architectural Science Association,* 423–433. 2015.
[19] Joseph, C. L. and S. C. M. Hui. "A review of building energy standards and implications for Hong Kong." *Building Research and Information* 24, no. 3 (1996): 27–29.
[20] Tang, C. K. and Nic Chin. *Building energy efficiency technical guideline for passive design*. Building Sector Energy Efficiency Project (BSEEP), Malaysia, 2013.
[21] ASHRAE Standard 90.1-1989. Energy efficient design of new buildings except low-rise residential buildings. 1989.
[22] Malaysian Standard MS 1525:2001. Energy efficiency and use of renewable energy for non-residential buildings. Code of practice. 2001.
[23] Malaysian Standard MS 1525:2007. Energy efficiency and use of renewable energy for non-residential buildings. Code of practice. 2007.
[24] Djamila, Harimi and Chi-Ming Chu. "Prediction of hourly diffuse solar radiation in Malaysia." In *First Seminar on Engineering and Information Technology, Kota Kinabalu, Sabah, Malaysia,* 59–61, 2008.
[25] Reimann, Gregers Peter, M. P. Davis, and A. Zain-Ahmed. "Malaysian weather data (TRY) for energy simulations in buildings." In *World Renewable Energy Conference VI*, 571–574. 2000.
[26] Singapore Building Construction Authority. *Guidelines on envelope thermal transfer value for buildings*. Commissioner of Building Control, Singapore, 2004.
[27] Chuah Donald G. S. and S. L. Lee, eds. *Solar radiation in Malaysia. A study on availability and distribution of solar energy in Malaysia.* Oxford University Press, Singapore, 1984.
[28] Djamila, Harimi, Chi-Ming Chu, and Sivakumar Kumaresan. "Field study of thermal comfort in residential buildings in the equatorial hot-humid climate of Malaysia." *Building and Environment* 62, (2013): 133–142.
[29] Baylon Tham. "OTTV calculation." In *MGBC Northern Chapter Seminar*, 2016.
[30] Awang, Norati Artini, Haslinda Mohamed Kamar, and Nazri Kamsah. "Energy saving potential of an air-conditioner – ice thermal storage (AC-ITS) system." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 31, no. 1 (2017): 1–10.
[31] Kamar, Haslinda, Nazri Kamsah, and Kam Jia Liq. "Indoor air of a double-storey residential house in Malaysia." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 31, no. 1 (2017): 11–18.