The European Proceedings of
Multidisciplinary Sciences
EpMS

ISSN: 2421-826X

https://doi.org/10.15405/epms.2019.12.30

ICRP 2019

4th International Conference on Rebuilding Place

THE EFFECTS OF NIGHT-TIME SIMULATION USING VERTICAL GREENERY SYSTEM IN HIGH-RISE BUILDING

Hazril Sherney Basher (a)*, Sabarinah Sh. Ahmad (b)
*Corresponding author

(a) School of Housing, Building, and Planning, Universiti Sains Malaysia, 11800, Penang, Malaysia, hazril@usm.my
(b) Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia

Abstract

Vertical Greenery System (VGS) is a passive thermal strategy in urban high-rise which implements vegetation in front of building facades. The purpose of having VGS is to absorb heat gain due to urban heat island that affects the outdoor and also indoor environment. This paper investigates the possibility of having greenery on residential balcony in order to improve the internal thermal performance and minimize electricity consumption. Due to increasing usage of air conditioning system (A/C) during night-time, this paper will focus on the effects of using VGS using simulation of test rooms on ground level and 8th storey level located in Putra Place Condominium Penang. This paper presents an extended series of night-time simulation data from the use of VGS. The findings are based on the use of Integrated Environmental Solutions Software (IESVE) and are validated using existing measured data. The results of VGS application will compare the indoor thermal performance between a control room (without vegetation) and VGS room (with vegetation).Overall, it supports the fact that having vegetation on high rise level will significantly minimize the indoor air temperature (DBT) more effective when compared to ground level application. The night-time study showed that the wall surface with VGS absorbed less and emits even less heat gain into the internal spaces. Therefore, having vegetation as passive shading strategy will increase the building efficiency and eventually reduce air conditioning system usage.

Keywords: Vertical greenery system, high-rise, night-time, temperature reduction.

https://doi.org/10.15405/epms.2019.12.30
Corresponding Author: Hazril Sherney Basher
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2421-826X

1. Introduction

Migration trend from rural to major urban cities is considered a global phenomenon in recent years. An estimate of 40.6 million Malaysians would migrate to urban cities by the year 2020 (Department of Statistics Malaysia, 2013). Moreover, United Nations (2018) added that at least 55% of the world population nowadays settled in urban cities and is expected to rise by the year 2050 up to 68%. Therefore, residential developers must confront with the increasing numbers of over population by developing more high-rise residential. When this developing trend occurs at larger scale, vegetation is replaced with manmade fixtures that often contribute to urban heat island (UHI). Eventually this will also lead to climate changes and global warming (Shakun et al., 2012).

To overcome this issue, one of the passive strategies of minimising the urban heat island (UHI) effects is by improving the building facades. Several researchers have conducted studies on the improvements and impact of using different facade treatment strategies or by using multiple shading devices. The external building facades treatment or external shading can either be made of building materials or even living plants. For example, a study conducted by Shahdan, Ahmad, and Hussin (2018) reviewed multiple shading devices in the form of louvers, fins and even egg-crate wall system that could minimise the internal heat gain. In addition, living plants such as green facades, vertical planters and even modular system such as living wall system (LWS) has also contributed to the reduction of indoor air temperature and minimise urban heat island (UHI). This research will only emphasize on using vertical greenery system (VGS) as one of the main strategies to optimize the building indoor thermal performance (Gracia et al., 2017; Taib & Prihatmanti, 2018).

The definition of VGS is also known as vertical green facade that is installed on building elevations and also transitional spaces such as balcony or corridor (Jaafar, Said, Reba, & Rasidi, 2013). Moreover, Wong et al. (2010) pioneered the VGS terminology stated that the VGS is best known as integration between modular system and vertical greenery. The VGS has many benefits not just reduce indoor air temperature. Other than that, it could help to filter out the airborne pollutants as well as to improve the thermal comfort (Prihatmanti & Taib, 2017). In this paper, the VGS focused on green facade with indirect greening feature that applies onto planter box system which is cheaper and easy to maintain. The VGS in this paper is represented using a ‘topographical shade’ which is a feature inside the IESVE simulation tool software. The VGS is simulated using green facade thermal properties that will be explained later in the research methods section.

When compared to existing shading device such as louvers or egg crate wall system, the VGS is able to reduce the indoor air temperatures more efficiently by absorbing the heat gain and also alters the ambient temperatures through the process of evaporative cooling. This paper will focus on the extension reading of VGS effect towards night-time study on high rise residential compared with ground level. As stated by Ahmad (2004), air conditioning system tend to be used majority during night-time. The heat gain is absorbed by wall and glazing facades drastically during daytime as there are no solution to shading device towards facades that facing east or west orientation sunlight.

https://doi.org/10.15405/epms.2019.12.30
Corresponding Author: Hazril Sherney Basher
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2421-826X

2. Problem Statement

Solar heat gain is one of the most dominant issue related to today's houses. In low-rise buildings, solar heat gain may transfer through the buildings' envelopes such as roofs or un-shaded external walls. However, in terms of high-rise buildings, the highest form of heat gain in a building envelope is through fenestrations such as glazing of windows and sliding doors (MS1525:2014). As mentioned by Lam, Tsang, Li, and Cheung, (2005), high-rise buildings are keen on using glazing material as curtain walls and sliding doors. These features allow daylight to penetrate deeper within the interior surface and at the same time brings heat gain through solar radiation. It creates thermal discomfort as most of the sunlight penetrates directly into the building through heat conduction and radiation, depending on the facades' orientation and window wall ratio (WWR).

Due to the use of inferior materials with high u-value, the intolerable high-rise unit has pushed the building occupant to extensively consume massive electricity. The high-rise residential occupant tends to use air conditioning system (A/C) more excessively compared to ceiling fans to achieve desirable thermal comfort. Zain-Ahmed (2009) stated that the normal residential living will consume at least 50% of the total electricity consumption. This is supported by Szokolay (2014) mentioning that urban dwellers are keen to use split unit system that will actually resolve thermal discomfort. When the split unit system operates, it emits heat gain from the outdoor unit. According to Ng, Chen, Wang, and Yuan, (2012), the overuse of electricity to power the A/C unit has increase both electricity bill and urban heat island. This uncontrollable urban heat island effect has increased the thermal discomfort of building occupant inside and also the outdoor spaces as well. This is due to high absorption of heat gain in the form of solar energy that stored inside the building facades during daytime. Majority of building occupant turn to A/C unit during nigh-time in spaces such as bedrooms and living areas that faces west orientation in daytime. According to Giridharan, Lau, Ganesan, and Givoni, (2008), urban heat island could also affect the country areas at night-time. The author classified it as 'urban heat island intensity' which is cause by lack of cooling and also due to higher solar emission absorbed from the building façade at daytime. Highly built up areas in cities would release heat from the solar radiation trapped in their hard surfaces at night and slow down the rate of night cooling from the atmosphere, hence causing the latent effect of night cooling.

Figure 1 indicates the overall energy balance from the use of VGS. Generally, a building façade will receive diffused, direct or reflected radiation (R). In this process, Susorova (2013) stated that there will be an interchange wave radiation from the sky to the ground surfaces. More over the author added that the solar radiation which is absorbed by the façade will either be transferred into the indoor space by conduction (Q) or emitted to the outdoor surrounding using convection (C). After a period, energy from the sun radiation will be accumulated inside the facade material (S). According to Ottelé, Perini, Fraaij, Haas, and Raiteri (2011), the stored energy that has been absorbed by the wall façade will be reradiated back as sensible heat. While according to Asan (2006), building material such as brick wall will have thermal lag process which is a time delay for the material to absorb and reradiated back. Normally the brick wall will store the heat gain for 6 hours depending on thermal properties. This is why during night-time; the internal space appears to be hotter than daytime. To resolve the whole solar radiation process, it is important to install the VGS material in order to intercept the heat transfer from outside to indoor space. This will give the chance for VGS thermal properties to cool the surrounding spaces using evaporative cooling or called 'evapo-transpiration'(E).

3. Research Questions

- What is the maximum internal temperature drop of using greeneries (VGS) in residential balcony?
- What is the effect of VGS during night-time study compare to daytime?

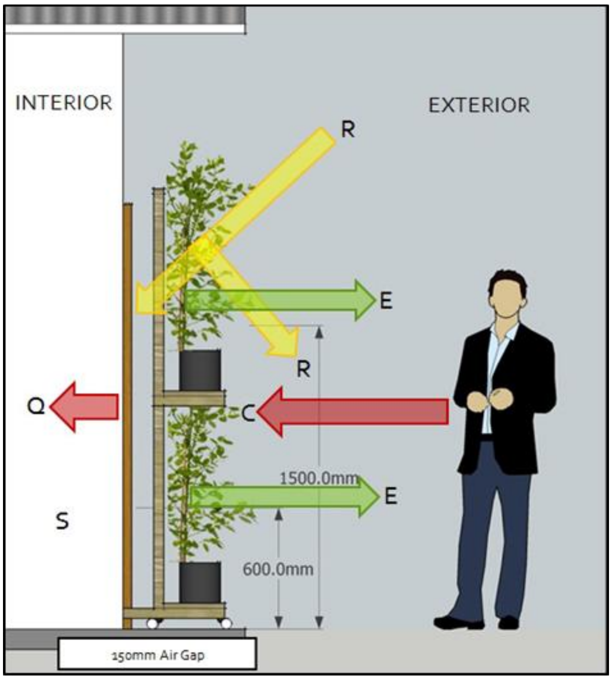

Figure 01. VGS Energy Balance (Basher, Ahmad, Malek, & Rahman, 2016; Fukaihah, 2013); C: Convection, E: 'Evapotranspiration', R: Wave Radiation, S: Stored Energy, Q: Conduction.

4. Purpose of the Study

The purpose of this paper is to investigate the possibility of having greenery on residential balcony in order to improve the outdoor and indoor thermal performance. In addition it also focusing on minimizing electricity consumption. Due to increasing usage of air conditioning system (A/C) during night-time, this paper will focus on the effects of using VGS using simulation of test rooms on ground level and 8th storey level located in Putra Place Condominium Penang. This paper presents an extended series of night-time simulation data from the use of VGS.

5. Research Methods

This paper will focus on the use of simulation modelling that replicates existing field measurement techniques. The building energy simulation program involved in this simulation modelling is IESVE software. This program will allow the user to generate three dimensional modelling of desired spaces via 'Model-it'. After that, the 3d generated model will be simulated using a 'SunCast' tool programme. This software functions as building shading analysis. Finally, the 'Apache-sim' tool is used for thermal analysis. The main results are then generated using 'Vista-pro' which in turn describes comparison between readings before (without VGS) and after (with VGS) in the form of graphs.

This paper will investigate the maximum temperature drop for internal and external condition that caters daytime and night time study. This paper will discuss the effect of VGS during night-time or overnight study (19:00 to 07:00). The VGS facade wall (1.8m x 2.1m) that placed in front of both ground floor and high-rise test unit is replicated into a 'topographical shade'; a feature that is used to represent VGS wall in 3D modelling (Basher, 2017). There is some limitation towards the IESVE software which is unable to replicate evaporative cooling effect from real vertical plants. Therefore, this alternative is used. It is placed in front of a condo unit (ground level) and on the 8th floor of the same building. The test rooms were located at Bayan Lepas, Penang Malaysia. To ensure software validity, the final results are based the weather data provided by IESVE and paired with the Meteorological Department Penang (Malaysian Meteorological Department, 2009).

Larsen, Filippín, and Lesino (2014) proved that the creation of a simple geometric wall or 'building shading object' would have the same thermal behaviour of a normal VGS material due to similar long wave radiation. Hence, this approach is chosen in IESVE software tool. An alternative material namely compressed wood panel, which has a thermal transmittance of 0.25 W/m²K was used in the simulation as a replication to the VGS wall. This test is designed to observe how it affects the model indoor environment similar to the field measurement findings conducted by Basher et al. (2016). According to Basher (2017) and Pullen (2017), the VGS wall is replicated using a low u-value material. Thus, the lower the u-value, the less heat is transferred to the indoor spaces.

The simulation high-rise unit is generated to replicate existing high-rise condo apartment in Bayan Lepas Penang that uses exact size of test room model for ground and 8th floor level. The area of the test unit is about 15 meter square. The test units were facing west orientation. This is to ensure the simulation replicated the worst condition scenario compared to other orientations (Susorova, Azimi, & Stephens, 2014). In order to achieve better results, the simulation models were running in parallel session. Data simulated are logged for five clear days and were set for 24 hours with logged in data at one hour interval.

6. Findings

From the simulation modelling of Table 1 and Figure 2, the control readings measured a mean ambient air temperature of 27.26°C. At this condition, the mean control internal dry bulb temperature (DBT) (without vegetation) was estimated at 31.32°C. The implementation of VGS (with vegetation), shows that the indoor temperature line had rose and fell gradually as the indoor air temperature fell by 0.45°C to 30.87°C. Figure 2 also indicates that the VGS performs well during night time signify by night-time study sample as the indoor VGS trend is consistently below the control indoor DBT. However, the temperature differential was rather low as the readings are quite similar and almost parallel together to those taken during daytime. In terms of thermal performance effect during night time, the results indicated that utilisation of VGS recorded emit less heat gain into the internal space during night time due to early thermal absorption and shading capacities of the VGS wall during the daytime.

Table 01. Ground Level VGS Thermal Performance

Time / Mean	Amb. Temp. Control °C	Amb. Temp. VGS °C	Indoor DBT Control °C	Indoor DBT VGS °C	Avg. Temp. Reduction °C
Mean/Avg	27.26	27.26	31.32	30.87	0.45
Mean Max	31.5	31.5	32.84	32.2	
Mean Min	23.8	23.8	29.87	29.52	

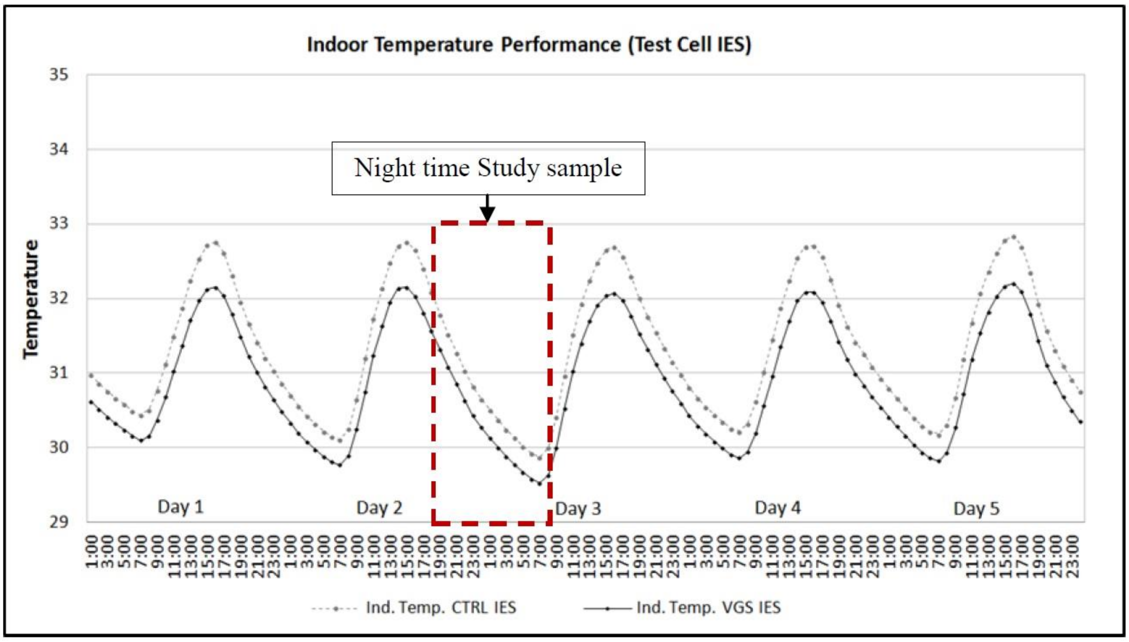

Figure 02. Ground Level VGS Thermal Performance

For the high-rise thermal performance (Table 2 and Figure 3), it revealed that the room shaded by the VGS had a 1.24°C indoor DBT drop. At this point, the indoor DBT of the room shaded by the VGS generated a reading of 30.76°C. For the (without vegetation) condition was approximately 32.00°C. From the readings, the indoor air temperature reduction was slightly higher if compare to previous findings of application of VGS in ground level data with differential at least 0.75°C. The increase in control temperature (without vegetation) could have been derived from excessive exposure of the sun in high-rise settings. In addition, differential between elevations from ground to upper storeys may improve the VGS thermal performance. The high-rise unit shaded by the VGS (with vegetation) also performed better during night-time period. Under these conditions, the VGS reduces and delays heat transfer continuously. The night-time period results highlight the fact that the utilisation of VGS emits even less heat gain into the internal space compared to ground level readings. This is highlighted in figure 3 night-time study sample where there is an increasing gap between 21:00 and 07:00. This is due to thermal performance and energy balance of VGS that utilises 'evapotranspiration' process that intercepts solar radiation at daytime. Thus, heat dissipation process for thermal reduction can be triggered for VGS to perform well.

From both readings, if the test room simulated using only control data (without vegetation), the room itself will fully absorb and emits heat gain during night time toward the ambient temperature making the building occupants to rely on fully air conditioning system slightly higher to achieve desired

https://doi.org/10.15405/epms.2019.12.30
Corresponding Author: Hazril Sherney Basher
Selection and peer-review under responsibility of the Organizing Committee of the conference
eISSN: 2421-826X

indoor thermal comfort level. However, if the VGS is applied onto the desired space at early stage to intercept solar radiation and heat gain this will allow even greater thermal performance during the night-time due to the lesser use of air conditioners or other means of artificial cooling just to the cool the indoor DBT spaces. Besides increasing elevations from ground level to higher level of 8th storey height, the other factors that triggered the VGS to perform well in high-rise conditions may occurred due to VGS covered plants that has smaller gaps between leaves foliage. This will allow efficiency in thermal reduction through heat dissipation process during night time as it does not obstruct the process along the way (Wong et al., 2010).

Table 02. High-rise Level VGS Thermal Performance

Time / Mean	Amb. Temp. Control °C	Amb. Temp. VGS °C	Indoor DBT Control °C	Indoor DBT VGS °C	Temp. Reduction °C
Mean/Avg.	26.60	26.60	32.00	30.76	1.24
Mean Max	32.0	32.0	34.72	32.82	
Mean Min	22.50	22.50	30.07	29.22	

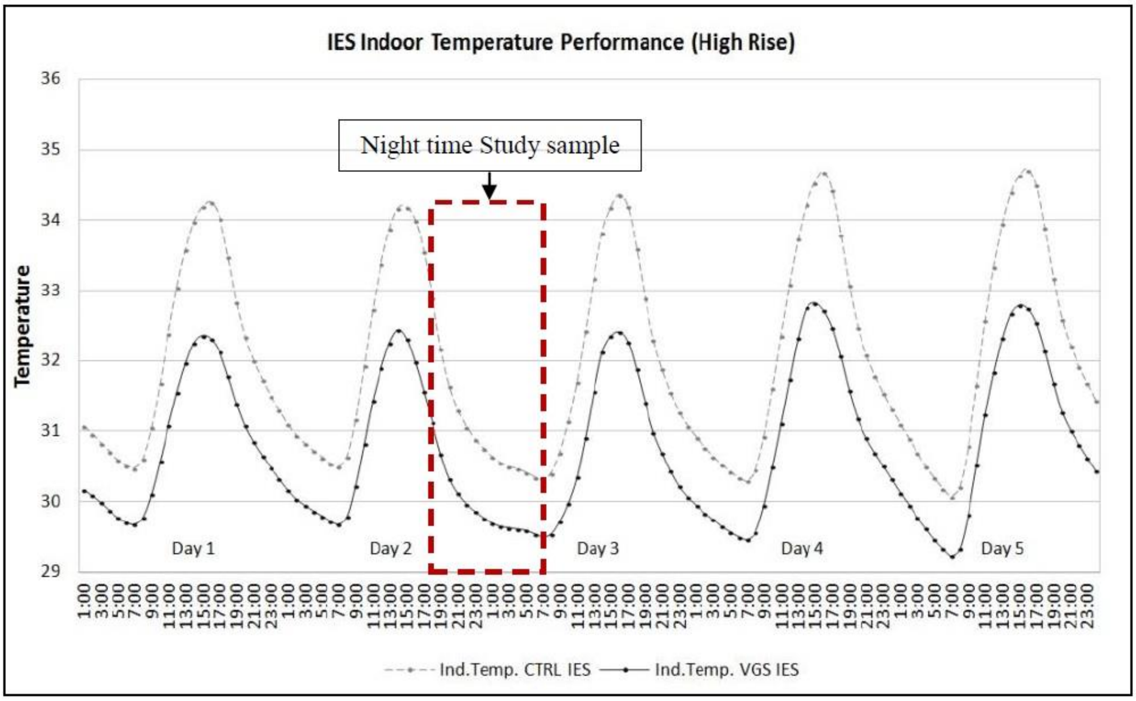

Figure 03. High-rise Level VGS Thermal Performance

7. Conclusion

From the simulation study, the use of VGS is able to improve thermal performance for daytime and night-time used as it is able to buffer and also reduces the heat gain entering into the indoor spaces. The VGS allows significant mean indoor temperature reduction of 0.45°C (low-rise) and 1.24°C (high-rise) due to differential level of receiving solar radiation. The higher the elevation, the more efficient will the VGS perform. In terms of night-time study, the VGS of low-rise test unit was not able to emit heat gain efficiently due to receiving less solar radiation during daytime. However, when the 8th storey test unit was simulated the readings indicated an improvement as the VGS was able to absorb the heat gain at early stage before it penetrates to the surface of glazing or wall material to produce evaporative cooling. Hence with the reading of 1.24°C indoor temperature, the VGS proof itself worthy compare to other manmade shading devices.

The VGS trend also showed improvement during night-time study as the readings indicated emitting even lesser heat gain towards outside so the ambient temperature will be cool enough during night-time. By having vegetation with fair gaps between foliage, the VGS can dissipate heat gain more effectively compared to other modular green facades in the market as there are no obstruction between wall and the VGS material. This is ultimately leading to lesser use of air conditioning unit during night-time especially in living spaces or bedroom areas in future research.

Acknowledgments

This study was funded by the School of Housing, Building, and Planning, Universiti Sains Malaysia.

References

Ahmad, S. S. (2004). A study on thermal comfort and energy performance of urban multistorey residential buildings in Malaysia. University of Queensland.

Asan, H. (2006). Numerical computation of time lags and decrement factors for different building materials. *Building and Environment*, *41*(5), 615–620.

Basher, H. S. (2017). Simulation of Vertical Greenery System in Reducing Energy Cooling Loads for High Rise Residential Building. *Journal of Mechanical Engineering*, *2*(1), 185–196.

Basher, H. S., Ahmad, S. S., Malek, A., & Rahman, A. (2016). The Use of Edible Vertical Greenery System to Improve Thermal Performance in Tropical Climate. *Journal of Mechanical Engineering*, *13*(1), 57–66.

Department of Statistics, Malaysia (2013). Department of Statistics, Malaysia.

Fukaihah, A. (2013). Environmental And Thermal Performance Of Legumes As Biofacade In A Tropical Climate for the (Degree of Doctor of Philosophy).

Giridharan, R., Lau, S. S. Y., Ganesan, S., & Givoni, B. (2008). Lowering the outdoor temperature in high-rise high-density residential developments of coastal Hong Kong: The vegetation influence. *Building and Environment*, *43*(10), 1583–1595. https://doi.org/10.1016/j.buildenv.2007.10.003

Gracia, A. De, Bur, S., Cabeza, L. F., Coma, J., Pérez, G., de Gracia, A., … & Cabeza, L. F. (2017). Vertical greenery systems for energy savings in buildings: A comparative study between green walls and green facades. *Building and Environment*, *111*, 228–237. https://doi.org/10.1016/j.buildenv.2016.11.014

Jaafar, B., Said, I., Reba, M. N. M., & Rasidi, M. H. (2013). Impact of Vertical Greenery System on Internal Building Corridors in the Tropic. *Procedia - Social and Behavioral Sciences*, *105*, 558–568. https://doi.org/10.1016/j.sbspro.2013.11.059

Lam, J. C., Tsang, C. L., Li, D. H. W., & Cheung, S. O. (2005). Residential building envelope heat gain and cooling energy requirements. *Energy*, *30*(7), 933–951. https://doi.org/10.1016/j.energy.2004.07.001

Larsen, S. F., Filippín, C., & Lesino, G. (2014). Thermal simulation of a double skin façade with plants. *Energy Procedia*, *57*, 1763–1772. https://doi.org/10.1016/j.egypro.2014.10.165

Malaysian Meteorological Department. (2009). *Climate Change Scenarios for Malaysia Scientific Report 2001-2099*. Numerical Weather Prediction Development Section Technical Development

Division, Malaysian Meteorological Department Ministry of Science, Technology and Innovation Kuala Lumpur.

Ng, E., Chen, L., Wang, Y., & Yuan, C. (2012). A study on the cooling effects of greening in a high-density city: An experience from Hong Kong. *Building and Environment*, *47*, 256–271. https://doi.org/10.1016/j.buildenv.2011.07.014

Ottelé, M., Perini, K., Fraaij, A. L. A., Haas, E. M., & Raiteri, R. (2011). Comparative life cycle analysis for green façades and living wall systems. *Energy and Buildings*, *43*(12), 3419–3429. https://doi.org/10.1016/j.enbuild.2011.09.010

Prihatmanti, R., & Taib, N. (2017). Improving thermal comfort through vertical greeneries in transitional spaces for the tropical climate: A review. Journal of Engineering Technology, *4*(3), 116-123.

Pullen, T. (2017). Homebuilding & Renovating. Retrieved July 1, 2017, from https://www.homebuilding.co.uk/how-to-choose-a-sips-system/

Shahdan, M. S., Ahmad, S. S., & Hussin, M. A. (2018). External shading devices for energy efficient building. *IOP Conference Series: Earth and Environmental Science*. https://doi.org/10.1088/1755-1315/117/1/012034

Shakun, J. D., Clark, P. U., He, F., Marcott, S. a., Mix, A. C., Liu, Z., … Bard, E. (2012). Global warming preceded by increasing carbon dioxide concentrations during the last deglaciation. *Nature*, *484*(7392), 49–54. https://doi.org/10.1038/nature10915

Susorova, I. (2013). *Evaluation of the effects of vegetation and green walls on building thermal performance and energy consumption*. Illinois Institute of Technology.

Susorova, I., Azimi, P., & Stephens, B. (2014). The effects of climbing vegetation on the local microclimate , thermal performance , and air infiltration of four building facade orientations. *Building and Environment*, *76*, 113–124. https://doi.org/10.1016/j.buildenv.2014.03.011

Szokolay, S. V. (2014). *Introduction to architectural science: the basis of sustainable design*. Routledge.

Taib, N., & Prihatmanti, R. (2018). Optimising balcony for green spaces: Application of edible biofaçade on urban high-rise setting. *Planning Malaysia*, *16*(4), 92–103.

United Nations (2018). 2018 revision of world urbanization prospects. Retrieved from https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization prospects.html

Wong, N. H., Kwang Tan, A. Y., Chen, Y., Sekar, K., Tan, P. Y., Chan, D., … Wong, N. C. (2010). Thermal evaluation of vertical greenery systems for building walls. *Building and Environment*, *45*(3), 663–672. https://doi.org/10.1016/j.buildenv.2009.08.005

Zain-Ahmed, A. (2009). *Climate change, green technology and sustainable buildings.* Selangor, Malaysia: University Publication Centre, UiTM.