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# Natural Ventilation Potential in Kuala Lumpur: Assumptions, Realities and Future

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**Abstract:** Malaysia accounts for 11% of Southeast Asia's carbon emissions in recent years, is the third highest emissions contributor in the region. It has been estimated that 25% of these carbon emissions are generated from the buildings, especially from the electrical and mechanical equipment that are present in residential buildings. Malaysia's capital, Kuala Lumpur, has 81.5% of the high-rise buildings in the country and half of the buildings are residential. They have supposedly been designed as predominantly naturally ventilated, but the occupants had to add inefficient mechanical ventilation to achieve the required cooling. It is due to the lack of acknowledgement of the hot-humid climate of Malaysia by the current building regulations and the fact that the requirements for energy use are not customised for residential buildings. Recent developments concerning the use of green rating tools are helping to improve the sustainable design of buildings. This paper reviews these existing regulations and green rating tools and explores the full potential for natural ventilation in Kuala Lumpur, to substantially reduce carbon emissions while considering both the health and comfort of the occupants. It concludes that the building regulations should be revised to deal with current and future climatic conditions and to achieve the critical conditions that allow for natural ventilation in Kuala Lumpur.

**Keywords**: Natural ventilation, indoor comfort, indoor air quality, building regulations, Kuala Lumpur

## Introduction

The implications of climate change, including heat stress and air pollution, contribute to a wide range of impacts on human's health and comfort in urban areas (IPCC, 2014). More than half of the carbon emissions in the world, that are causing the climate change, will be produced by Asian cities in the next 20 years and it is estimated that 1.2 billion Asians will migrate to the cities over the next 35 years (ADB, 2015).

The carbon emission in the Southeast Asia (SEA) region has increased rapidly from 1990 to 2010 (ADB, 2015). Five countries that are Indonesia, Malaysia, Philippines, Thailand and Vietnam, have collectively contributed 90% of the carbon emissions in the SEA region (Raitzer et al., 2015). Malaysia accounts for the 11% of these emissions in recent years, ranking as the third highest emission contributor in 2014 (ADB, 2015). In order to address this problem, the government of the country has recently signed the Paris Agreement, committing to reduce 45% of carbon emissions by 2030 in accordance to the 2005 baseline (UNFCCC, 2017).

The building sector is one of the largest carbon emissions contributors in the world (IPCC, 2014). In the case of Malaysia, the carbon emissions from this particular sector have been doubled from the 1970s, representing now the 25% of the total country's emissions (Lucon et al., 2014). The residential buildings, construction of which has been quintupled during the last four decades (Lucon et al., 2014), and in particular their mechanical and electrical cooling equipment are the greatest contributors to the emissions. Thereafter, the appropriate ventilation design in these residential buildings, in particular high-risers, is a key element to find solutions to reduce carbon emissions and to overcome the damaging effects of climate change in the future. For example, the buildings in the urban areas such as Malaysia's capital, Kuala Lumpur. There are many challenges concerning the provision of natural ventilation in dense urban areas such as Kuala Lumpur, including the problems associated with the urban heat island effect and air pollution. The current practices in building design have failed to achieve the required environmental conditions for health and comfort and the occupants had to afterwards increase the amount of mechanical ventilation to achieve cooling.

The current building regulations in Malaysia (UBBL) were implemented in 1984 and these are based on the recommendations provided by the United Kingdom's Building Research Station (BRS), which is currently known as Building Research Establishment (BRE); these recommendations were previously applied in Kuala Lumpur and Singapore, both British colonies until 1957 (Said, 2011). The UBBL 1984 does not take Malaysia's hot-humid climate and the issues concerning carbon emissions in full account (Mohd Sahabuddin and Gonzalez-Longo, 2015). The regulations establish that the minimum size of openings for natural ventilation purposes in residential buildings should not be less than 10% of the total clear area of the room (UBBL, 2013), a requirement which remained unchanged for 33 years. There have been recent developments concerning the use of green rating tools in Malaysia, which are helping to improve the sustainable design of buildings and the health of their occupants. This paper reviews these existing regulations and green rating tools and explores the full potential for natural ventilation in Kuala Lumpur, in order to substantially reduce carbon emissions while ensuring a healthy and comfortable internal environment for the occupants of high-rise residential buildings.

## Identifying the critical issues for natural ventilation in consolidated urban areas

Kuala Lumpur accommodates 81.5% of the total number of high-rise buildings in Malaysia, and half of these buildings are residential buildings (CTBUH, 2016). Although most of these buildings were initially designed as naturally ventilated, the majority of their occupants have included inefficient mechanical ventilation to achieve indoor cooling (Aflaki et al., 2016). Other capital cities in the SEA region, such as Singapore and Bangkok, have also experienced the same problem (Aldossary et al., 2016, Oswald and Riewe, 2013).

The three common factors associated with indoor discomfort and unhealthy environment in high-rise residential buildings in SEA cities are high air temperature, high air pollution and low air movement. The high ambient air temperature resulted from urban heat island effects, is the result of the combination of direct solar radiation, diffused radiation from the sky dome and reflected radiation from both adjacent buildings and hard surfaces in urban areas. It has increased heat penetrates into indoor spaces through convection, conduction and radiation mechanisms (Chenvidyakarn, 2013, Nave, 2012).

The high levels of carbon emissions are directly linked to increments in temperature (Lucon et al., 2014). The scientific report of Climate Change Scenarios for Malaysia 2001-2099 produced by the Malaysian Meteorological Department (MMD) in 2009, has projected a temperature increment of 1.1$^{o}$C to 3.6$^{o}$C by 2095 in Peninsular Malaysia. It has also been recorded that the average dry-bulb temperature in Kuala Lumpur in 2015, was 27$^{o}$C and that by 2050 this figure is expected to increase by 1.2$^{o}$C (ESRI, 2015, MMD, 2010 - 2016).

As in many other cities, air pollution causes unhealthy environment in Kuala Lumpur's urban areas, as it contains airborne particulate matter and toxic gases from fuel vehicles, (Leh et al., 2012). Moreover, during the dry months of February to March and June to August in the past few decades, haze has become a regular event in Kuala Lumpur (Payus et al., 2013, Elsayed, 2012).

Both temperature and pollution issues are worsened by the insufficient wind movement in Kuala Lumpur, potentially reducing the possibilities of natural ventilation (Payus et al., 2013, Tahir et al., 2010). The city's average monthly wind speed was 1.1 m/s in 2015 (MMD, 2010 - 2016); this low figure together with the high air temperature, the presence of airborne particulate matter and urban roughness produce a series of challenges in order to implement natural ventilation strategies in buildings within the city. These factors have been so far considered in isolation and it is necessary to analyse them in an integrated way to inform the design which allows achieving a healthier and more comfortable indoor environment in high-rise residential buildings in an urban area in hot-humid climate such as Kuala Lumpur while reducing carbon emissions (Fig. 1).

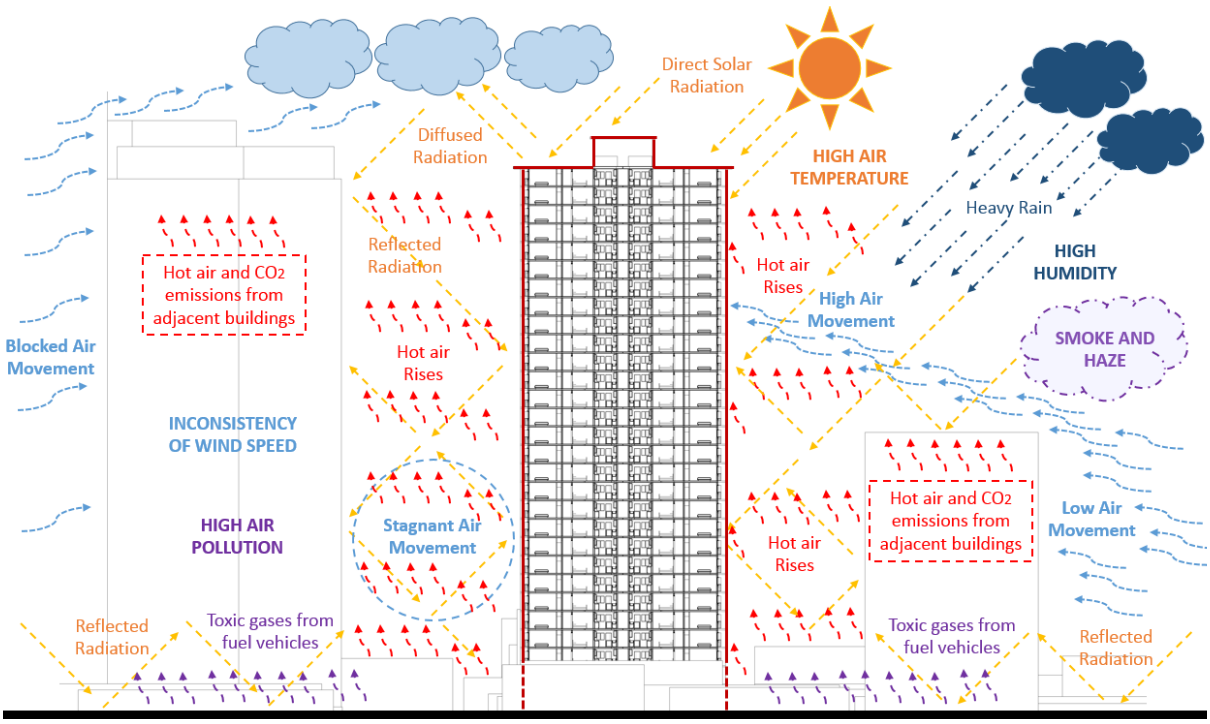


Figure 1: Factors affecting natural ventilation in a typical high-rise building within an urban area in hot-humid climate

## Current Building Regulations, Standards and Green Ratings

The mandatory building regulations in Malaysia are called the 'Uniform Building By-Laws' (UBBL) 1984 and are contained within the 'Street, Drainage and Building Act' (SDBA) 1974. The requirements for natural ventilation in residential buildings are established in the 3$^{rd}$ part of the regulations: 'Space, Light and Ventilation' under clauses 39(1), 39(4), 40(1) and 40(2). However, they are only concerned about the proportion of windows and size of light-wells and there are not more specific regulations on achieving healthy indoor air quality.

Clause 39(1) states that '*every room designed, adapted or used for residential purposes, shall be provided with natural ventilation by means of one or more windows having a total area of not less than 10% of the clear floor area of such room and shall have openings capable of allowing a free uninterrupted passage of air of not less than 5% of such floor area*' (UBBL, 2013). Clause 39(4) determines that '*every water-closet, latrine, urinal and bathroom* *should be provided with natural ventilation by means of one or more openings having a total area of not less than 0.2 sqm*' from the room's total area (UBBL, 2013).

For buildings that are more than 8 storied high, clause 40(1), establishes that the minimum size of light-wells should be not less than 15 sqm, being the minimum width 2.5 meters and clause 40(2) requires the minimum size of each light-well for lavatories, water closets and bathrooms shall be 5.5 sqm and 2.0 meters minimum width (UBBL, 2013). These could not provide an acceptable ventilation by natural means in high-rise residential buildings where weaker stack effect due to lower temperature differences and heat build-up at the top of the light-wells might happen at certain levels (Prajongsan, 2014, Kotani et al., 2003).

Concerning energy use, UBBL 1984 only refers to the Malaysian Standard 1525:2014 - 'Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings', which proposes several passive design strategies for natural ventilation such as cross ventilation and stack ventilation. However, the standard only suggests using $CO_2$ sensors to control indoor air pollution. For indoor comfort cooling in air-conditioned spaces, this standard recommends the maximum air movement of 0.7 m/s and air temperature of 24$^{o}$C to 26$^{o}$C.

Malaysia, like many other countries, has recently developed several green rating tools. Three most popular green rating tools used by both private and public sectors, are the Green Building Index (GBI), the Green Real Estate (GreenRE) and Malaysian Carbon Reduction & Environmental Sustainability Tool (MyCREST). However, only GBI and GreenRE have been used for residential buildings so far (MGBC, 2014, REHDA, 2015).

The first green rating tool used in Malaysia was the GBI, initiated in 2009 by a private organisation, the Malaysian Green Building Corporation (MGBC, 2014). Until October 2015, approximately 327 buildings have been rated by GBI and 41% of them are residential (MGBC, 2017). Although the tool refers to UBBL 1984 for minimum percentage of openings, in its latest version for 'Residential New Construction' published in 2014, some natural ventilation strategies have been proposed. These include the provision of light-wells to promote the stack effect (as we have seen already considered by UBBL), open plan layouts to promote cross ventilation, shading devices or overhangs to protect windows from sun radiation and naturally ventilated public spaces. This rating tool also encourages the use of low Volatile Organic Compounds (VOC) materials and finishes to reduce the indoor air pollutants, but there is no minimum air movement and indoor air temperature recommendation.

Another private organisation, the Real Estate Housing Development Association, created GreenRE in 2013 (REHDA, 2015). This tool proposes several strategies to enhance natural ventilation in residential buildings. In addition to the strategies previously proposed by GBI such as the use of open plan layouts to promote cross ventilation and the provision of public spaces naturally ventilated, GreenRE encourages a more appropriate orientation of buildings, so that they face prevailing winds. The latest version of the tool, 'Design Reference Guide for Residential Building and Landed Home' published in 2015, recommends a provision of no less than 0.6 m/s average air movement in indoor spaces (REHDA, 2015) and avoiding VOC materials to achieve good indoor air quality. As in the case of GBI there are no recommendations for the minimum percentage of openings or indoor air temperature set.

MyCREST was created by a collaborative effort of several government agencies such as the Ministry of Works, Public Works Department of Malaysia (PWD) and the Construction Industry Development Board Malaysia (CIDB) in 2016 (CIDB, 2016). This document is at the moment available only for non-residential buildings. In order to maintain good quality in the indoor air, this tool requires that all naturally ventilated spaces should be '*permanently open to and within 7.6 meters of operable wall or roof openings and that operable area is at least*

*4% of the net occupiable area'* (CIDB, 2016). This figure is much lower than the 10% required by Clause 39 in UBBL 1984 and researchers have considered that the minimum opening percentage in high-rise residential buildings should be not considered equally and should have a variety of sizes depending on the location and height (Mohd Sahabuddin and Gonzalez-Longo, 2015). MyCREST proposes that the minimum average of air movement for naturally ventilated spaces should be no less than 0.6 m/s. Similar to the other two green rating tools, MyCREST considers that the sources of air pollution are mainly from materials that contain VOC only (CIDB, 2016).

Table 1: Comparison of natural ventilation strategies in the laws, standards, and green rating tools in Malaysia

| | **PARAMETERS (Established) (Latest Version)** | **UBBL (1984) (2013)** | **MS:1525 (2001) (2014)** | **GBI (2009) (2014)** | **GreenRE (2013) (2015)** | **MyCREST (2016) (2016)** |
|---|---|---|---|---|---|---|
| **EXTERNAL** | Suggest minimum percentage (%) of openings of the clear floor area | 10% | - | - | - | 4% |
| | Suggest minimum percentage (%) of uninterrupted openings | 5% | - | - | - | - |
| | Suggest recesses, shading devices, or overhangs | - | √ | √ | - | √ |
| | Suggest louvres and wing walls | - | √ | - | - | √ |
| | Use vented skylights | - | - | - | - | √ |
| **INTERNAL** | Suggest to promote ventilation through adjoining rooms | - | - | - | - | √ |
| | Suggest internal air speed | - | *0.7 m/s | - | >0.6 m/s | 0.6 m/s |
| | Use cross Ventilation | - | √ | √ | √ | √ |
| | Implement open plan arrangement | - | √ | √ | √ | √ |
| | Suggest roof space be ventilated | - | - | - | - | √ |
| | Suggest to use mechanical equipment | - | √ | - | - | √ |
| | Provide light-well or wind chimney to promote stack effect | $15m^2$ (> 8 stories) | √ | √ | - | - |
| | Suggest internal air temperature | - | *24-26$^{o}$C | - | - | - |
| **ETC** | Suggest all public spaces should be naturally ventilated | √ | √ | √ | √ | √ |
| | Provide wind direction table | - | - | - | - | √ |
| | Suggest buildings should face prevailing winds | - | √ | - | √ | √ |
| ***** | For residential buildings | √ | - | √ | √ | - |
| | Suggest passive method to reduce airborne particulate matter from incoming air intake | - | - | - | - | - |
| *For air-conditioned spaces | | | | | | |

This entire situation in the current scenario is concerned about the regulations and green rating tools, needs some clarification concerning the parameters they consider. Table 1 shows the comparison of natural ventilation strategies in the regulations, standards and the green rating tools used in Malaysia, as discussed above. Although there are significant improvements, in particular, the development of the recent MyCREST tool, Malaysia needs to address the need for a revision of its building regulations so that residential buildings are designed to minimise their carbon emissions and to improve the health and comfort of the occupants.

**Learning from the Vernacular Architecture**

In the residential buildings at tropical regions cooling is more important than heating. According to the chapter of 'Buildings: Mitigation of Climate Change' in the 5th Climate Change Assessment Report produced by the Intergovernmental Panel on Climate Change (IPCC) in 2014, residential buildings in tropical regions could lower the carbon emissions by introducing a design that could maintain indoor comfort temperatures without using any mechanical equipment. The clear precedent is vernacular houses, which design have succeeded in achieving cooling and comfort (Lucon et al., 2014). Although, obviously, they were not built in a dense urban context such as Kuala Lumpur.

In the case of traditional houses in Malaysia, it took hundreds of years to refine a well-adapted design to the local climate. The key factors for achieving healthy indoor comfort in Malaysia's rural areas are the integration of building form, the use of lightweight materials and green surroundings. Large overhangs, for example, prevent direct solar radiation and rain from entering the houses and timber-gap-floor on stilts promote fresh air intake from beneath the floor. High pitched roofs with ventilation at the top exhaust warm air by the stack effect. Lightweight materials immediately release solar heat (Lim, 1987), and large openings on the facades, which effectively balance the external and internal air temperatures (Kubota and Toe, 2015). An integrated natural ventilation strategy informed by these vernacular precedents has a great potential to reduce carbon emissions directly and at the same time ensuring the health and increased comfort of the occupants.

A study on the possible adaptation of these vernacular strategies to a modern social housing building has proved that an appropriate envelope and layout configuration could achieve the acceptable operative temperature of 25.2$^{o}$C to 27.2$^{o}$C, increase the indoor air movement up to 80% and reduce 67% of the carbon emission as well as energy consumption (Mohd Sahabuddin and Gonzalez-Longo, 2015). This study, which has introduced the concept of an 'Airhouse' standard for hot-humid climates, established that the percentage of openings in the building façade should be between 15% to 45% depending on the height of the residential units, increasing or decreasing the area depending non the height of the residential unit. A full-height opening configuration was proposed with three elements and these are - main windows, fixed louvres and adjustable louvres. Fixed louvres are introduced at the upper level of the internal walls to allow air to circulate throughout the units at every time. The proposed standard has also suggested that the depth of rooms should be decreased to enhance cross ventilation and the overhangs should be provided to protect all windows from solar radiation at any angles. Further studies are being carried out to refine and validate the standard.

**Conclusion and recommendations**

Although current building regulations, standards and green rating tools have proposed many natural ventilation strategies in Malaysia, they have not been able to acknowledge the current and future climatic conditions of Kuala Lumpur. At the same time, they are not able to address the required improvements in occupant's health and comfort as well as the reduction of the carbon emissions. The UBBL, especially the clauses 39(1) and 40(1) that regulate sizes of openings and light well requirements, were informed by British building standards and have not been reviewed and further researched in accordance with local climate conditions. These clauses, which have been used for 33 years without revision, should be revised and improved in order to reduce carbon emissions while ensuring occupant's health and comfort. Likewise, the standards (MS1525:2014) and green rating tools (GBI, GreenRE and MyCREST) have failed to devise strategies that could reduce airborne particulate matter and toxic gases as well as to prevent convective, conductive and radiative heat from entering and permeating high-rise residential units in Kuala Lumpur.

As per the clause 39(1), the minimum size of openings for ventilation purposes in a residential building in Malaysia should not less than 10% of the total clear area of the room. However, this sole figure seems to be inappropriate to provide ventilation and filter airborne particulate matter from entering indoor spaces in high-rise residential buildings due to different heights factor. Clause 40(1) of UBBL sets the requirement for a light-well of 15 sqm in buildings higher than 8 stories, which could not provide an acceptable ventilation by natural means in high-rise buildings due to weak stack effect and the absence of wind-force ventilation. Further studies should be carried out to test the appropriateness of these requirements to achieve suitable ventilation while ensuring the health of the building occupants and increase comfort levels in indoor spaces.

Building regulations in Malaysia, which are concerned about the natural ventilation, should be revised in order to reduce energy consumption and carbon emissions as well as to deal with the challenges of heat stress and air pollution which affect the comfort and health of the building's occupants. This revision should take into consideration the critical conditions, which allow for natural ventilation to enhance air movement, reduce the airborne particulate matter and maintain the acceptable operative temperature. By improving the regulations and maximising the potential of natural ventilation, high-rise residential buildings in Kuala Lumpur would become healthy and comfortable places to live in and great contributors to the mitigation of climate change.

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**References**

ADB, A. D. B.-. 2015. *Asia's Booming Cities Most At Risk from Climate Change* [Online]. Asian Development Bank. Available: https://www.adb.org/news/features/asias-booming-cities-most-risk-climate-change [Accessed].

Aflaki, A., Mahyuddin, N. & Baharum, M. R. 2016. The influence of single-sided ventilation towards the indoor thermal performance of high-rise residential building: A field study. *Energy and Buildings,* 126**,** 146-158.

Aldossary, A., Ali, Z. & Summ, W. M. 2016. To Do Away With Air Conditioning - Comfort With Natural Ventilation in Tropical High Rise. PLEA2016 - The 32nd Conference on Passive and Low Energy Architecture, 11-13 July 2016 Los Angeles, USA. 1694-1701.

Chenvidyakarn, T. 2013. *Buoyancy effects on natural ventilation*, Cambridge University Press.

CIDB 2016. MyCREST: A Reference Guide for Design Stage Certification. Kuala Lumpur: Construction Industry Development Board Malaysia (CIDB).

CTBUH, C. O. T. B. A. U. H.-. 2016. *The Skyscraper Center: The Global Tall Building Database of the CTBUH* [Online]. Available: http://skyscrapercenter.com/compare-data [Accessed].

Elsayed, I. S. 2012. Mitigation of the urban heat island of the city of Kuala Lumpur, Malaysia. *Middle-East Journal of Scientific Research,* 11**,** 1602-1613.

ESRI 2015. ArcGIS. Redlands, California.

IPCC 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. ,* Geneva, Switzerland, IPCC.

Kotani, H., Satoh, R. & Yamanaka, T. 2003. Natural ventilation of light well in high-rise apartment building. *Energy and Buildings,* 35**,** 427-434.

Kubota, T. & Toe, D. H. C. 2015. Application of Passive Cooling Techniques in Vernacular Houses to Modern Urban Houses: A Case Study of Malaysia. *Procedia-Social and Behavioral Sciences,* 179**,** 29-39.

Leh, O. L. H., Ahmad, S., Aiyub, K., Jani, Y. M. & Hwa, T. K. 2012. Urban air environmental health indicators for Kuala Lumpur city. *Sains Malaysiana,* 41**,** 179-191.

Lim, J. Y. 1987. *The Malay house: rediscovering Malaysia's indigenous shelter system/Lim Jee Yuan*, Institut Masyarakat.

Lucon, O., Ürge-Vorsatz, D., Ahmed, A. Z., Akbari, H., Bertoldi, P., Cabeza, L. F., Eyre, N., Gadgil, A., Harvey, L. D. D., Jiang, Y., Liphoto, E., Mirasgedis, S., Murakami, S., Parikh, J., Pyke, C. & Vilariño, M. V. 2014. Buildings. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *In:* [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. & Brunner, P. E., B. Kriemann, J. Savolainen, S. Schlömer, C. Von Stechow, T. Zwickel And J.C. Minx (Eds.)] (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

MGBC, M. G. B. C.-. 2014. Design Reference Guide – Residential New Construction (Rnc). Kuala Lumpur: GreenBuildingIndex Sdn Bhd.

MGBC, M. G. B. C.-. 2017. *Green Building Index: Executive Summary As 15 October 2015* [Online]. Kuala Lumpur. Available: http://www.greenbuildingindex.org/organisation-certified-buildings-Summary.html [Accessed 11 April 2017].

MMD, M. M. D.-. 2010 - 2016. Mean Surface Wind Speed for Petaling Jaya, Subang and Sepang Stations. Petaling Jaya.

Mohd Sahabuddin, M. F. & Gonzalez-Longo, C. 2015. Traditional values and their adaptation in social housing design: Towards a new typology and establishment of 'Air House'standard in Malaysia. *International Journal of Architectural Research: ArchNet-IJAR,* 9**,** 31-44.

Nave, C. R. 2012. HyperPhysics. *Department of Physics and Astronomy, Georgia State University. Retrieved January,* 16, 2017.

Oswald, F. & Riewe, R. 2013. Residential High-Rises without the usage of Air-Conditioning in Tropical Regions - A Case Study of the MET in Bangkok. *SB13 Graz - Sustainable Building Conference 2013***,** 768-778.

Payus, C., Abdullah, N. & Sulaiman, N. 2013. Airborne particulate matter and meteorological interactions during the haze period in Malaysia. *International Journal of Environmental Science and Development,* 4**,** 398.

Prajongsan, P. 2014. *Natural ventilation strategies to enhance human comfort in high-rise residential buildings in Thailand.* University of Liverpool.

Raitzer, D. A., Bosello, F., Tavoni, M., Orecchia, C., Marangoni, G. & Samson, J. N. G. 2015. *Southeast Asia and the Economics of Global Climate Stabilization*, Asian Development Bank.

REHDA 2015. Design Reference Guide – Residential Building & Landed Home. Petaling Jaya: GreenRE.

Said, B. H. M. 2011. *An overview of the Uniform Building By-Laws, 1984 & the Amendments 2007 [Part 3/5]* [Online]. Available: http://badrulhishamarchitect.blogspot.co.uk/2011/03/overview-of-uniform-building-by-laws_963.html [Accessed].

Tahir, M. M., Zain, M. F. M., Sopian, K., Usman, I. M. S., Surat, M., Abdullah, N. A. G., Tawil, N., Nor, M. & Che-Ani, A. I. 2010. *The Development of A Sustainably Responsive Ultra Low Energy Terrace Housing For The Tropics Incorporating The Raised Floor Innovation*.

UBBL, U. B. B.-L.-. 2013. Laws of Malaysia (Act 133): Uniform Building By-Law 1984 (UBBL). *In:* DEPARTMENT, L. G. (ed.) Sixteenth Edition ed. Kuala Lumpur: MDC Publishers Sdn Bhd.

UNFCCC, U. N. F. C. O. C. C. 2017. *UN Climate Change: Paris Agreement* [Online]. Bonn, Germany. Available: http://newsroom.unfccc.int/paris-agreement/ [Accessed].