

THE EFFECT OF RESIDENTIAL ROOM CONFIGURATION ON NATURAL VENTILATION OF RUSUN UNITS TO ACHIEVE LOW ENERGY BUILDING

Megan Afkasiga Ririhena^{1*}, Nedyomukti Imam Syafii²

^{1,2}Department of Architecture and Planning, Universitas Gadjah Mada

*Correspondence: meganafkasiga@mail.ugm.ac.id

Abstract

Rusun is a simple flat categorized as Affordable Housing (AH), which means it requires economic energy efficiency and optimal Natural Ventilation (NV) to manifest and provide comfort for users. This research will review the effect of spatial configuration on NV conditions of Rusun unit in terms of the condition of wind flow (WF) and wind speed (WS) value in each residential room by simulation method.

The condition of the unit is on the 10th floor and height of 31.5m with an outdoor WS of 1.62 m/s in three different space configurations. It was found from the simulation that residential space that has direct access from openings both inlet and exit (outlet) has a more optimal WF and WS. From the WF condition and WS value following the needs of residential user activities, it is expected to optimize NV in Rusun units and in line with that, can realize energy-efficient Rusun buildings in terms of occupancy.

History:

Received: February 23, 2021

Accepted: April 5, 2021

First published online:

July 29, 2021

Keywords:

Rusun
Natural Ventilation
Wind

1. Introduction

Countries in Southeast Asia have experienced economic growth that has resulted in rapid urbanization growth in recent years, increasing urban energy consumption. Air Conditioner (AC) usage has the highest percentage of 56% in countries in Southeast Asia (Katili et al., 2015). One of the countries in Southeast Asia, Indonesia, has spent 80% of the total social program budget on energy subsidies over the past ten years (Chen et al., 2020). According to BPS (Badan Pusat Statistik) Indonesia, housing development in Indonesia has reached 15 million units in around 2014-2015. The condition can be exacerbated by the growth of about 800,000 new households each year (Bunawardi et al., 2016). To overcome, the Indonesian government has targeted 1 million dwellings per year starting from 2015.

In Indonesia, which tends to be hot and humid, most of the dwellings that are now developed are medium and tall buildings. Indonesia generally has three types of apartments/flats, namely simple flats (Rusun), medium flats (Apartments), and luxury flats (Kondomium) (Bunawardi et al., 2016). Rusun itself can be categorized as Affordable Housing (AH). AH development is very different from commodity housing (CH), usually characterized by low construction costs, uniformity of housing and a short construction development period (Gan et al., 2017). AH is a type of housing with limited price segmentation or rent that the government provides for low-income households.

To balance investment, AH buildings must have high economic efficiency (Adabre et al., 2020). In addition to price affordability, the need for space flexibility is increasing rapidly (Warouw et al., 2010). Space flexibility is related to adaptability for space changes, including mobility and transformation of space in terms of color, lighting, texture, etc. (Schwartz-Claus & von Vegesack, 2002). Related to the flexibility of limited space usage,

especially in the delivery, it requires optimal natural ventilation (NV) conditions to provide comfort to Rusun users.

A residential building has energy conservation standards with a passive and active solar energy utilization control index. To dispose of the heat energy that facilities receive from sunlight, at least a heat sink mechanism such as soil, atmosphere, or body of water is required. Passive cooling system, utilizing this mechanism to condition the deep space without the use of conventional mechanical systems, such as air conditioning. Compared to air conditioning systems, passive cooling systems consume little energy, require little maintenance, are cheap and environmentally friendly.

However, the effectiveness of this passive cooling system largely depends on the climate and typology of the building. NV is an effective way to reduce energy use and provide thermal comfort to high-rise residential buildings (Sha & Qi, 2020). NV types can be classified into two main types, namely, cross ventilation (CV), where the openings are located on two parallel walls, and single-sided ventilation (SSV) spaces located on the same side of the wall (Evola & Popov, 2006). This research will see how the potential application of CV for comfortable and energy-efficient housing with modeling simulation method when reviewed from the influence of spatial configuration on the unit compared using wind flow (WF) and wind speed (WS) parameters in some samples of Rusun units in Indonesia.

Liping and Hien analyzed the effect of building sheaths on indoor thermal conditions in buildings applying NV with parametric facade study methods of various orientations, window sizes, and brewing devices with building simulation and CFD in May and October in Singapore. The results found that the ratio of window to

wall with a value of 0.24 and horizontal brewing device 600mm at each orientation significantly influences thermal comfort (Wang & Hien, 2006). Miyazaki and Yamamoto analyzed the effects of thermal insulation, including outer walls and window glass, on reducing residential cooling energy consumption in Cambodia by simulation. The simulation results showed a sound effect of thermal insulation (Miyazaki et al., 2012).

Cho simulated CFDs using the Wind Tunnel method on high-level buildings in South Korea to see how it would affect the operable window with the principle of single-side ventilation (SSV). Of the five alternative types of SSV found that wind effects can strengthen or fight each other by tracking airflow patterns in the space of different kinds of operable windows (Cho et al., 2012). Sugiyama and Yasufuku evaluated the effects of natural ventilation, combined with thermal insulation and solar shading, to achieve heat comfort and reduce the burden of residential cooling in Malaysia. It is proven that the combination can lower the average operating temperature to 28.5°C (Sugiyama et al., 2015).

Yueer inspects buildings with natural ventilation in humid summer zones and proposes air-based enthalpy based on energy conservation assessment methods. Results show that natural ventilation effectively improves thermal comfort while maintaining low cooling of energy consumption in humid summer zones. Using NV can help reduce cooling energy by 10–30% compared to not using NV (He et al., 2017).

2. Methodology

The research method uses the modeling simulation method. The definition of simulation is a representation of the behavior or characteristics of a system through the use of other systems, especially computer programs designed for that purpose (dictionary.com). Simulation research emerges from broader human interest with replication (mimesis & imitation) of real-world objects and settings (Wang & Groat, 2013). Modeling simulation can save time and provide controllable results following the specified requirements (Wang & Hien, 2006).

Simulation method using Rhinoceros software to model from typical Rusun unit, grasshopper software to perform algorithm analysis and butterfly with indoor airflow method to find WF in each unit room Rusun. The value for NV analysis is derived from air pressure between indoor and outdoor air caused by wind and indoor temperature (Cho et al., 2012). The airflow value due to the difference in wind pressure in the outer chamber and the unit space in the unit room is based on the boutet equation (Satwiko, 2004).

where,

$$Q_p = C_v A C m^3/s \tag{1}$$

Q_p = air flowing through the window (m^3/s)

C_v = effectiveness of openings (0.5-0.6 when the wind direction comes perpendicular to the opening, 0.25-0.35 when the direction of the window diagonal wind)

A = effective opening area (m)

V = wind speed (m/s)

Rusun building model that will be simulated has 16 total floors with floor to floor (FF) 3.15m, and unit ventilation openings (inlet) are located in the north and south of the building (Figure 1). Data wind speed (WS) average annually in inputs from EnergyPlus Weather (EPW) city of Jakarta Indonesia with Field visualized through Ladybug. The unit to be simulated is on the middle floor (MF) building is the 10th floor with a height of 31.5 m from the ground level with a wind speed of 1.62 m/s from the north of the building.

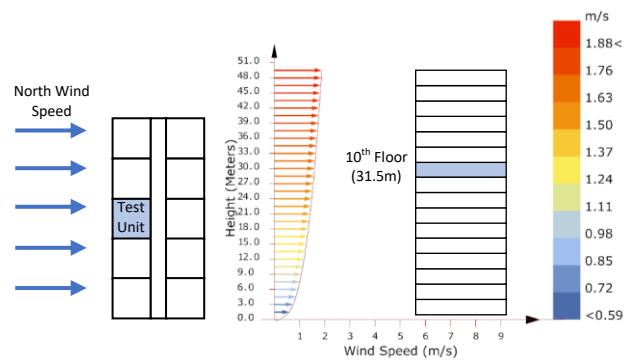


Figure 1. Outdoor Wind Conditions

The study used several samples from the typical rusunawa unit room in Indonesia both that had been built and in the planning stage with an area of ±30m2 namely, Rusunawa Jatinegara Barat (Unit 1), Rusunawa Sleman (Unit 2) and Rusunawa PUPR Ngampilan (Unit 3). The height of the area analyzed in the room is 1.3m from the floor of the unit.

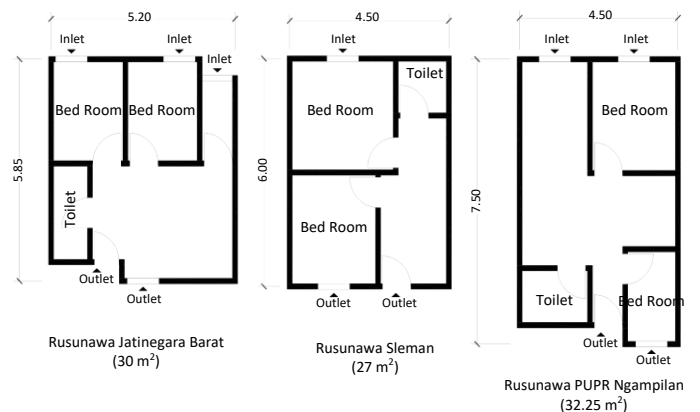


Figure 2. Simulation Unit

Each unit to be simulated has almost the same floor area but has a typical different room configuration by having two bedrooms (B), a living room (L), a toilet (T), and unit 1 that has one dryer room (D).

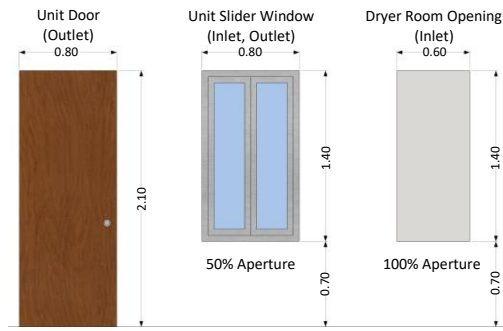


Figure 3. Dimensions of Inlet and Outlet Unit

Inlets and outlets have the same dimensions but different locations and amounts that will affect air

3. Result & Discussion

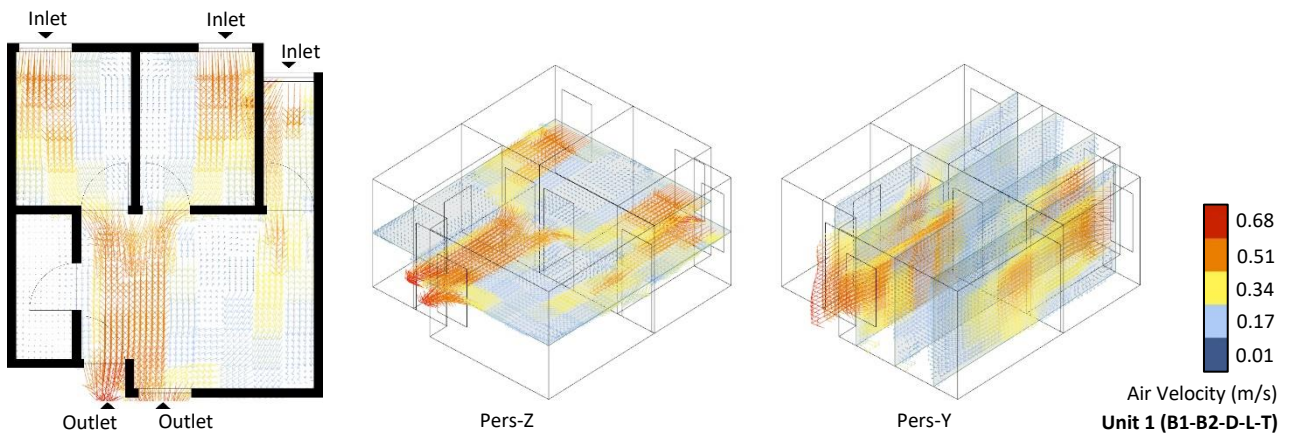


Figure 4. WF Unit 1 (B1-B2-D-L-T)

In unit 1 (B1-B2-D-L-T):

1. Turbulence is created in room B1 and B2 due to the cross position between the window (inlet) and the room door.
2. After exiting room B1 and B2, WF directly passes through room L to the exit (outlet) which is perpendicular to room door B1 and B2.
3. A little turbulence is created in room L obtained from room D

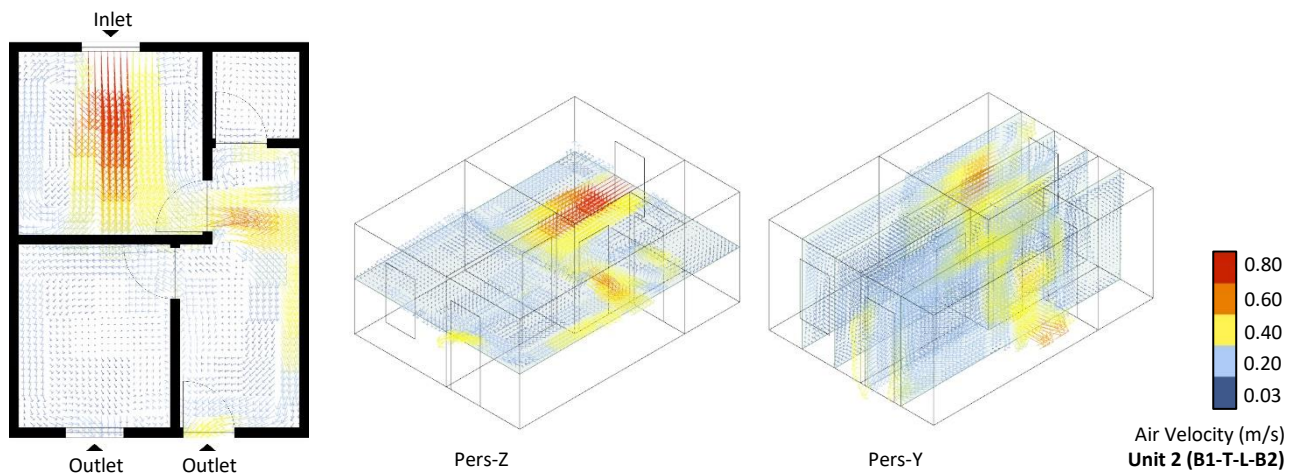


Figure 5. WF Unit 2 (B1-T-L-B2)

In unit 2 (B1-T-L-B2):

1. There is a large turbulence and WS in room B1.
2. Turbulence is created in room L due to the close wall distance to the door of room B1.
3. WF from room L to B2, but not too big and creates a bit of turbulence

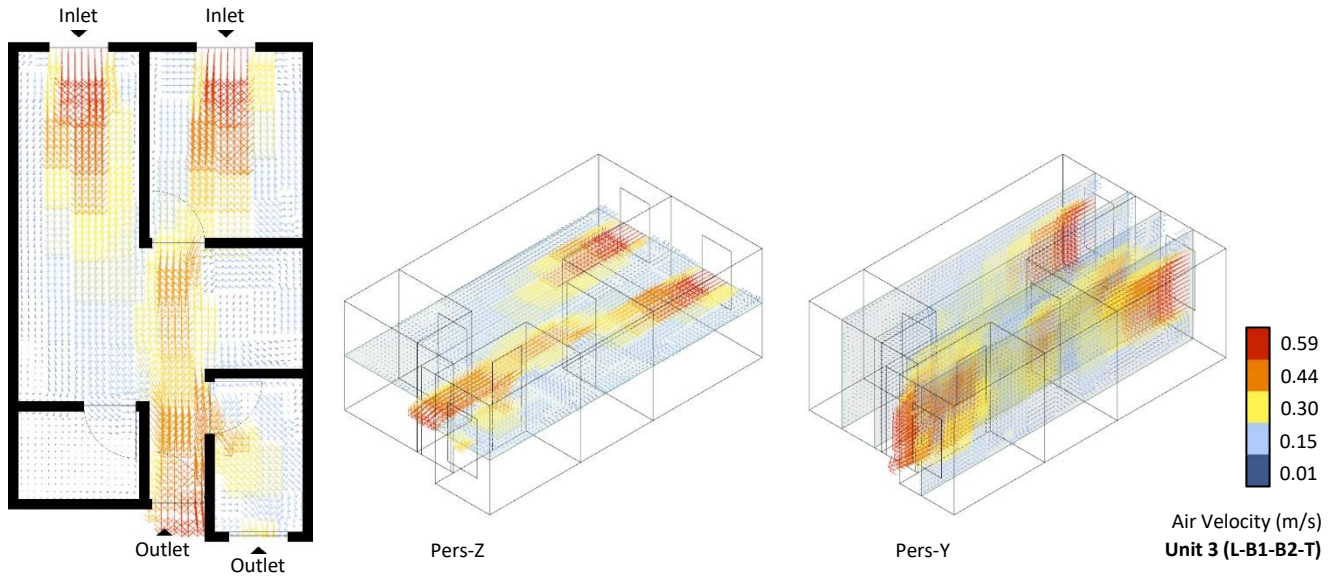


Figure 6. WF Unit 3 (L-B1-B2-T)

In unit 3 (L-B1-B2-T):

1. Turbulence occurred in room B1 due to the cross position between the window (inlet) and the room door
2. WF in room L is quite large with a bit of turbulence.
3. Room B2 has a large enough WF and turbulence obtained from WF room L and that comes out of room B1 with a perpendicular direction to the exit of the unit (outlet)
4. WF value in unit 3 outlet is quite large because of the hallway created from B2 and T space that is quite close.

Based on three WF simulation results in each unit of the Rusun above (Figure 4;5;6) that apply cross ventilation (CV) principles on the unit can be said following the theory that has been researched before. The creation of turbulence in the residential space from the flow of air that enters through the inlet of the Rusun unit and shrinks when there is turbulence in the room. Then WS again increased when moving to the next room through the door of the room, shrinking again when there was turbulence in the next room and again increased when exiting through the outlet unit Rusun.

WF and WS conditions in each unit of Rusun simulated at an altitude of 31.5m from ground level, s and 1.3m from the floor surface of the unit have differences with each other when conditioned with the same outdoor WS.

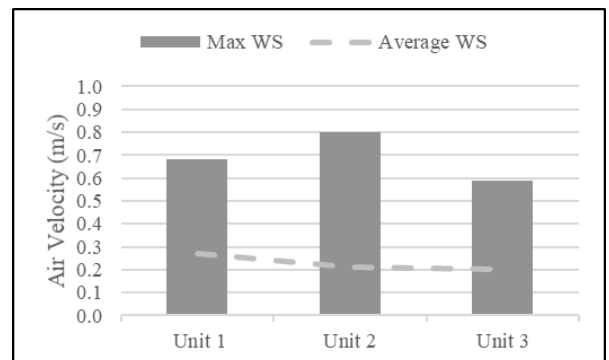


Figure 7. Maximum and Average of WS Units Diagram

The first difference is because the volume of air flow entering the unit of the inlet is influenced by the ratio of the area of inlet openings and outlets in each Unit Rusun. The comparison of maximum WS and average WS in units 1 and 3 has an equation where the higher the maximum WS, the higher the average WS of the whole unit, in contrast to unit 2 where the maximum WS has a value far enough with the average WS unit. Unit 1 has a WS interval value between 0.00-0.68 m/s with an average WS value of 0.27 m/s in one unit. Unit 2 has a WS interval value between 0.03-0.80 m/s with an average WS value of 0.21 m/s in one unit. Unit 3 has a WS interval value between 0.01-0.59 m/s with an average WS value of 0.20 m/s in one unit.

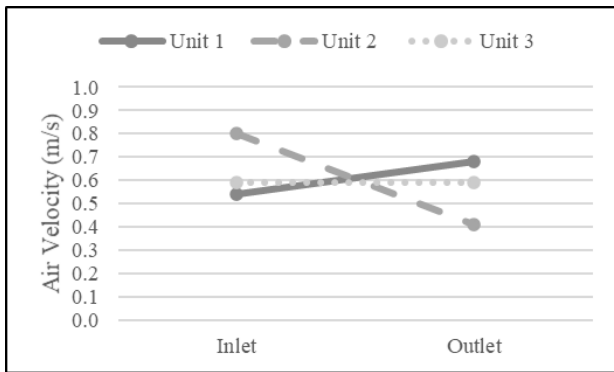


Figure 8. WS of Inlet and Outlet Units Diagram

Another difference is the comparison of WS in inlets and outlets that experience differences between each unit (Figure 8). In unit 1, where the percentage of openings is inlet > outlet, unit 2, where the percentage is inlet < outlet, unit 3 has the percentage inlet = outlet. In unit 1, WS value increased by 0.14 m/s with WS inlet 0.54 m/s and WS outlet value of 0.68 m/s. In unit 2, WS value decreased between inlet and outlet by 0.39 m/s with WS inlet value of 0.80 m/s and outlet value of 0.41 m/s. In unit 3 has an equation of WS value between inlet and outlet which is 0.59 m/s.

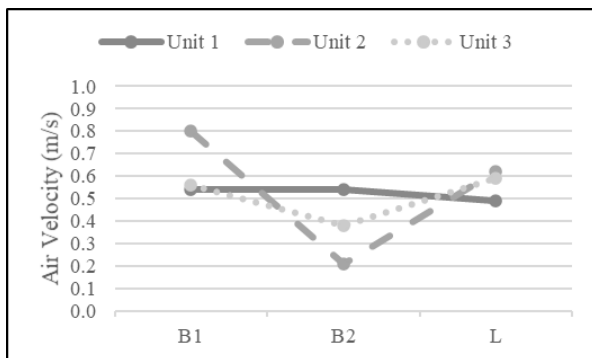


Figure 9. Maximum WS of Residential Space Units Diagram

Each unit has a difference of WS in each residential space (B1, B2, L) when reviewed with the highest WS at one of the WF points of the room. In unit 1, where each residential room has access to openings directly from the inlet, WF and WS values tend to be the same in each residential space. In unit 2 only has one inlet, namely in B1 has a high WS value of 0.80 m/s in room B1, while in a small B2 room with a value of WS 0.21 m/s. In unit 3, which has access openings from an inlet in room B1 and L have WS of 0.56 m/s and 0.59 m/s respectively and B2 room that has opening access from an outlet of 0.38 m/s. Unit 1 has the WS values equation at B1 and B2 of 0.54 m/s and L=0.49 m/s. Unit 2 has a value of WS B1=0.80 m/s, B2=0.21 m/s and L=0.62 m/s. In unit 3 have WS value B1=0.56 m/s, B2=0.38 m/s and L=0.59 m/s.

4. Conclusion

From the results of the research of the three units of the Rusun that have different configurations of space, has obtained:

1. It was found that for each residential room to get WF and a balanced WS value in each room, direct opening access is required in residential spaces both from inlets and outlets.
2. This research can reference academics as literature in conducting WF and WS analysis methods using Butterfly software. In future research and literature reference for design and construction practitioners in the design process of Rusun units in the design process when reviewed from WF and WS parameters of residential space with contextual, geographical conditions.
3. This research can be applied as a reference in the configuration of the interior furniture layout of the room so that activities in the residential space can get optimal WF and WS following the needs of residential room users without using artificial convention properties.

Further research is needed related to outdoor air entering each unit Rusun reviewed from outdoor air quality, indoor and outdoor air temperature and outdoor air conditioning to get optimal WS input value in the unit because NV is one of the comfort parameters for residents of Rusun due to limited use of artificial air.

References

- Adabre, M. A., Chan, A. P. C., Darko, A., Osei-Kyei, R., Abidoye, R., & Adjei-Kumi, T. (2020). Critical barriers to sustainability attainment in affordable housing: International construction professionals' perspective. *Journal of Cleaner Production*. <https://doi.org/10.1016/j.jclepro.2020.119995>
- Bunawardi, R. S., Suzuki, Y., & Yuasa, H. (2016). Diversity and utilization of public space in Rusunawa Mariso, Makassar – Indonesia. *Journal of Asian Architecture and Building Engineering*. <https://doi.org/10.3130/jaabe.15.433>
- Chen, Y., Mae, M., Taniguchi, K., Kojima, T., Mori, H., Trihamdani, A. R., Morita, K., & Sasajima, Y. (2020). Performance of passive design strategies in hot and humid regions. Case study: Tangerang, Indonesia. *Journal of Asian Architecture and Building Engineering*. <https://doi.org/10.1080/13467581.2020.1798775>
- Cho, J., Yoo, C., & Kim, Y. (2012). Effective opening area and installation location of windows for single sided natural ventilation in high-rise residences. *Journal of Asian Architecture and Building Engineering*. <https://doi.org/10.3130/jaabe.11.391>
- Evola, G., & Popov, V. (2006). Computational analysis of wind driven natural ventilation in buildings. *Energy and Buildings*. <https://doi.org/10.1016/j.enbuild.2005.08.008>
- Gan, X., Zuo, J., Wu, P., Wang, J., Chang, R., & Wen, T. (2017). How affordable housing becomes more sustainable? A stakeholder study. *Journal of*

- Cleaner Production.
<https://doi.org/10.1016/j.jclepro.2017.06.048>
- He, Y., Liu, M., Kvan, T., & Peng, S. (2017). An enthalpy-based energy savings estimation method targeting thermal comfort level in naturally ventilated buildings in hot-humid summer zones. *Applied Energy*.
<https://doi.org/10.1016/j.apenergy.2016.11.098>
- Katili, A. R., Boukhanouf, R., & Wilson, R. (2015). Space Cooling in Buildings in Hot and Humid Climates—A Review of the Effect of Humidity on the Applicability of Existing Cooling Techniques. *Proceedings of 14th International Conference on Sustainable Energy Technologies (SET)*.
<https://doi.org/10.13140/RG.2.1.3011.5287>
- Miyazaki, K., Yamamoto, Y., Washiya, S., & Takaguchi, H. (2012). Research on Mitigation Methods of Energy Consumption Increase Of Cambodian Houses. *Journal of Environmental Engineering (Transaction of Aij)*, 77(673), 193-202.
- Satwiko, P. (2004). *Fisika Bangunan*. Yogyakarta: Andi.
- Schwartz-Claus, M., & von Vegesack, A. (Eds.). (2002). *Living in motion: design and architecture for flexible dwelling*. Vitra Design Museum.
- Sha, H., & Qi, D. (2020). A Review of High-Rise Ventilation for Energy Efficiency and Safety. In *Sustainable Cities and Society*.
<https://doi.org/10.1016/j.scs.2019.101971>
- Sugiyama, S., Yasufuku, S., Kubota, T., & Toe, D. H. C. (2015). Effectiveness of energy-saving renovation techniques through passive cooling for urban houses in hot-humid climate of Malaysia. *Journal of Environmental Engineering (Japan)*.
<https://doi.org/10.3130/aije.80.673>
- Wang, D., & Groat, L. N. (2013). Architectural research methods / David Wang, Linda N. Groat. In *感染症誌*.
- Wang, L., & Hien, W. N. (2006). The impact of façade designs: Orientations, window to wall ratios and shading devices on indoor environment for naturally ventilated residential buildings in Singapore. *PLEA 2006 - 23rd International Conference on Passive and Low Energy Architecture, Conference Proceedings*.
- Warouw, F., Kobayashi, H., & Jung, J. (2010). A study on the open building system for multi-storey housing in Indonesia. *Journal of Asian Architecture and Building Engineering*.
<https://doi.org/10.3130>