Energy Saving Potential from Shading Design for Residential House in Rural Area

Dany Perwita Sari[1,2,*], and *Yun-shang* Chiou[1]

[1]NTUST, Architecture Department, Keelung Rd., Taipei 106, Taiwan
[2]LIPI, Research Center for Biomaterials, Jl. Raya Bogor, Cibinong 16911, Indonesia

Abstract. There are some architectural factors in the energy saving design of residential houses in Taiwan. In addition, in rural area, window glazing is a key factor to reducing electricity. For these purposes, a simulation model of exterior shading has been done in this study. Various types of shading devices have been analysed and compared in terms of energy savings. Simulation analysis by DesignBuilder reveals that shading devices has substantial impact to minimizing energy consumption. The results derived in this paper could provide useful suggestions for the shading design of residential buildings at rural area in Taiwan.

Key words: Energy saving potential, residential house, rural area, shading devices, subtropical climate

1 Introduction

Buildings sector contributed CO_2 emissions around the world. This results of high construction rates and the long lifespans of buildings [1]. It is clear seen that residential sector is one of the largest energy consumption sector in Taiwan, approximately 19 % in 2016 [2]. In other hand, Taiwan is lack of energy and more than 98.1 % of total energy supply is imported [3]. To meet the challenge of carbon reduction, conserving energy and energy efficient building design has been a concern for governments in Taiwan. They promoted green building in 1995, green building materials in 2004, and intelligent green building in 2010 [4]. By transforming the built environment to be more energy-efficient and climate-friendly, the building sector can play a major role in reducing climate change [1].

However, most of residential building in Taiwan is not designed by this regulation, especially in rural area (Figure 1). There are huge gap between urban and rural area for energy consumption because Government usually focused on newly building construction rather than conventional building. The conventional residential buildings in this subtropical climate of Taipei are normally focused on natural ventilation and solar shading. The numerous studies done on shading devices shows the importance of their usage in buildings [5, 6]. There are two location for shade in window, interior and exterior shading. Occupants tend to use blind to block the glare. Yun-shang Chiou and Yi-de Lin [7] introduced an experimental research using a portable testbed. The result indicate that blind system is only reduce the glare but not decrease the energy consumption. In another hand, the application

* Corresponding author: dany.perwitasari@gmail.com

of exterior shading devices are an essential issue for decreasing the cooling loads of building in hot climatic regions [8–10].

Fig. 1. Residential house at rural area in Taiwan. Left to right: house in Yilan, house in Guanshan.

Recently, building energy simulation has been developed as a new technique to predicted building energy consumption in early stages. The energy simulation engine will calculates the energy performance of several designs with faster and accurate. However, there is still a lack of studies analysing the impact of a shading design on the building energy consumption, especially in conventional residential building. Usually researcher only focused on newly building design. It is necessary to find optimal shading design solutions for conventional residential buildings considering both decreasing energy consumption and increasing indoor thermal comfort. In addition, designing and optimizing shadings is a complicated task. New strategy is needed to provide integrated software which can ease the design decision, modeling and solving problem.

This study makes an analysis a various shading design by using DesignBuilder. DesignBuilder allows the energy performance of a residential building. It also visualizes solar shading and investigates design alternatives to maximize thermal comfort, benefits of daylight and natural ventilation. To make the results more accurate, we used real occupant behaviour using Time Use Survey (TUS). Building simulation programs were used to demonstrate possible method of combining design and energy simulation with promises accuracy and appropriate data visualization technique [11]. This method allows architects to rely on an accurate analysis rather than on their intuition to make decisions. Therefore, designer and occupant will be easier to make decision which is the best shading design for conventional residential building in Taiwan.

2 Methodology and simulation set-up

Taiwan is classified as a subtropical area, which is characterized by hot and dry summers and cold winters. The hottest months are from June to August with the highest temperature reaching up to around 38 °C (100 °F). The average temperature of the rest of the months is around 25 °C (77 °F).

A whole building simulation using DesignBuilder was a suitable method that provides a valid decisions tool that use as shading analysis in conventional residential building. The digital model that DesignBuilder shows the user is similar to the original building. The important information that applies to the energy model has more to do with the building's construction, operations, and settings of HVAC systems. Moreover, DesignBuilder is working with a standard weather data.

In this study, simulations and analysis were made with DesignBuilder. With the aim to achieve correct and assessable data and results, the compliance of simulations with standard calculation methods is fundamental. TUS was chosen as an input variable in DesignBuilder.

TUS was record information about individual's activities during a 24 h period and personal information such as the individual's occupation and demographic background [12]. TUS data was used to establish a more reliable causal relationship between Taiwanese behaviour and residential energy use.

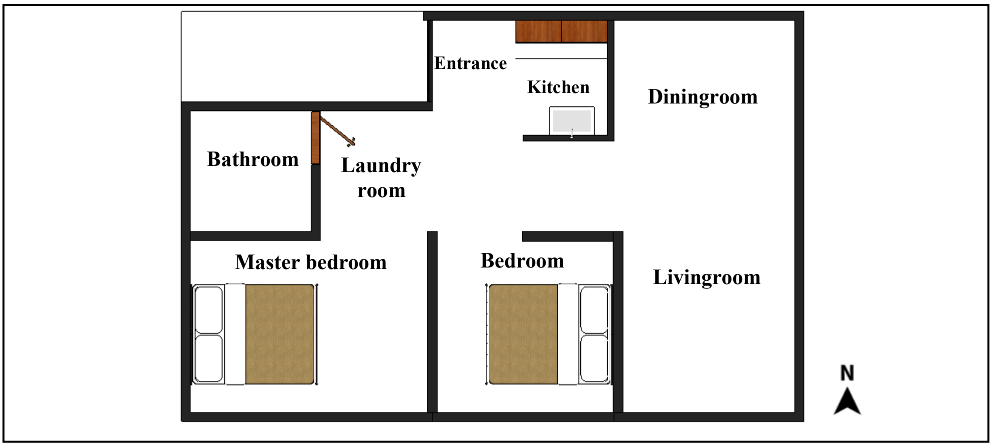

Fig. 2. Layout of space of residential building in rural area in Taiwan.

For the purpose of estimating the cooling load with various shading device, a prototype single house residential building has been established. The general configuration of the conventional residential building in Taiwan is one storey with four persons in one family. The total area of the house is 70 m^2. The whole bedroom and living room are oriented to the south (Figure 2). Designing external shading devices in existing buildings requires many design considerations, like aesthetics and integration with existing building style. This study proposes a simulation analysis of external shading devices that can be applied in conventional buildings. The current study deals with four different types of the shading device as shown in Figure 3: (i) overhang, which can control sunlight and not block the view; (ii) the horizontal louvers but they block most of the view; (iii) combined between overhang and side fin, this design can control sunlight in three sides and not block the view; (iv) mixed between overhang, side fin and horizontal louvers, which block most of the view to outside.

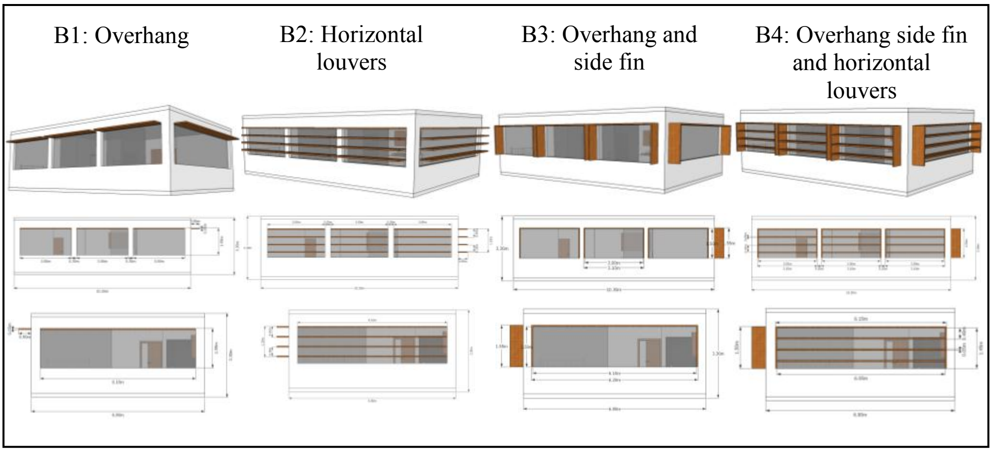

Fig. 3. Different types of window shading device for residential housing.

A whole building simulation using DesignBuilder was a suitable method that provides valid decisions tools to analysis shading devices. Figure 4 illustrates the flow of the proposed work flow methodology. The digital model that DesignBuilder shows the user is similar to the typical rural house in Taiwan. DesignBuilder is working with a standard weather data and occupant activity (TUS). Table 1 and Table 2 were shown the input data and material properties that have been applied to the energy simulation. The main purpose of analysis the shading devices is to control direct sunlight and to maintain thermal comfort, therefore can reduce the energy consumption. Another factor need to be taken into consideration in designing shading devices aside from blocking direct sun light and improve daylight quality is how to maintain a minimum level of contract with environment outside [10]. Contact with outside is an important factor to be anlyze in this research.

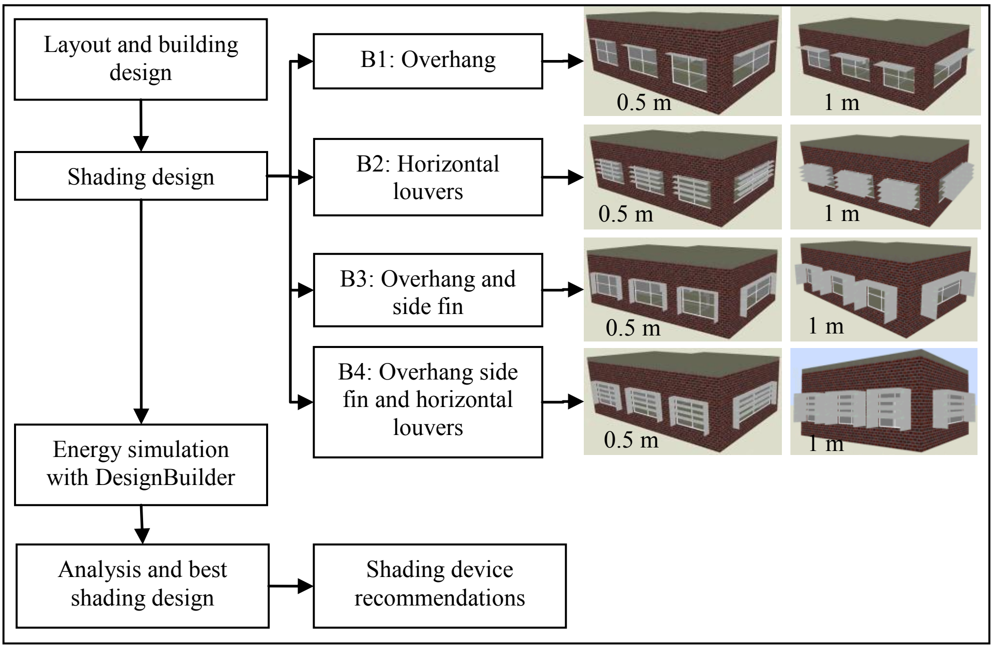

Fig. 4. Flowchart for conventional residential building with several shading devices.

Table 1. DesignBuilder simulation input data.

Variables	Values	
Design temperature	Cooling set-point	27 °C
Target luminance	-	150 lux
Minimum fresh air	Living room	7.5 (l/s-person)
	Bathroom	10 (l/s-person)
	Kitchen	12 (l/s-person)
Natural ventilation	-	27 °C
Weather data	Taiwan	-

Table 2. Material properties of building element.

Element	Construction	U-value (W/m^2K)
Wall	Concrete + ceramic tile	0.351
Foundation	Concrete	0.351
Floor	Ceramic	0.434
Roof	Flat roof	0.252
Internal partition	-	4.730
Windows	Clear glass	6.257

3. Results and Discussion

Results indicate a major influence of shading on solar gains, cooling load and visual environment of occupants. All shading devices helped reduce total electricity (Figure 5) all months in one year. It is clear that from May to September all shading devices reduce electricity higher than other months.

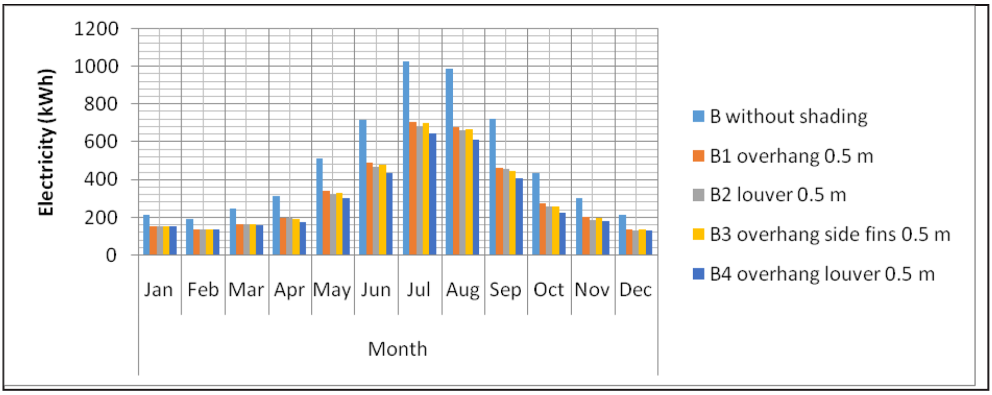

Fig. 5. The bar chart compare changes in total electricity (kWh) in conventional house B1 (overhang), B2 (louvers), B3 (overhang and side fins), B4 (overhang and louvers) compared to B (without shading).

It shows from Figure 6 that all shading devices in different size (0.5 m and 1 m) reduced the electricity by approximately the same rate. Moreover, B4, overhang and louvers design performed better than other shading devices. B1 and B3 shading devices has similar performance to lower the energy consumption rate. Graphically analysis (Figure 7) on solar gain exterior from window shows how each type of shading devices perform. Figure 7 show how the shading devices will perform all the time according to solar angel, altitude and azimuth.

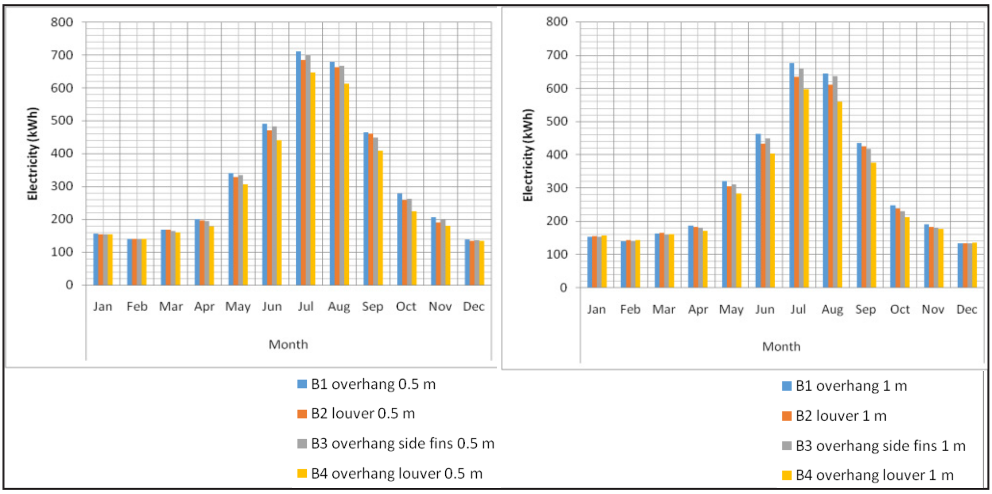

Fig. 6. The graphic was display comparison between shading devices (B1, B2, B3, B4) in different sizes (0.5 m and 1 m)

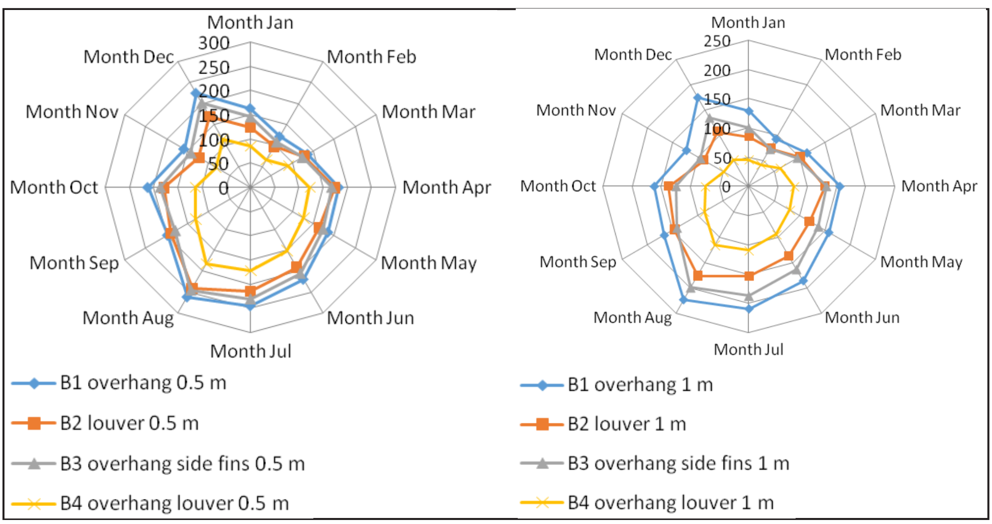

Fig. 7. Graphically analysis on solar gain exterior from window shows how B1, B2, B3, and B4 perform.

Figure 8 was display changes in electricity. Shading devices reduced electricity by up to 250 % in December, January and February respectively. In March the percentage difference in electricity consumption was around 200 %, while the difference starts to increase gradually as the increase amount of daylight in Taiwan latitude in April to November, with minimum reduction of 106 % in October. B1, overhang, as seen in Figure 8 was growth slowly from 259 % to 262 % from January to February. By contrast, electricity dropped sharply to 171 % in April, while from April to July electricity rose slowly to 222 %. Moreover, there was a fluctuated from August to December approximately 180 %.

B2 and B3 model showed a similar trend. This begin at slightly around 250 % in January also decreased at April at 160 % respectively, finishing the period at 170 %. However, the most significant was B4. Start in the same level like B1, B2 and B3 at January and February, and then B4 gradually decreased.

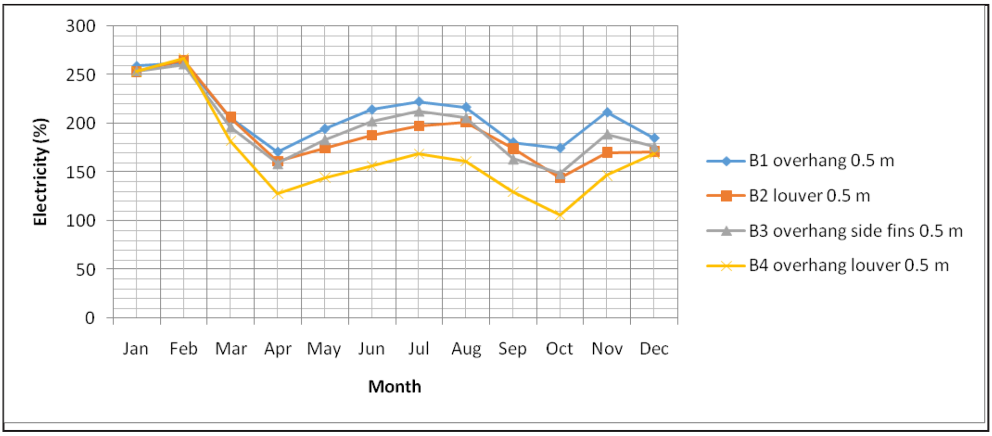

Fig. 8. Percentage results comparison between window without and with shading device. Model B4 was the best performance.

4. Conclusion

This paper discusses the simulation results of various shading devices for conventional house in rural area, Taiwan. In general, all shading devices helped to control the excessive daylight level and reduce glare. There was clear that all shading devices reduced the solar gain by approximately the same rate in December, January and February. By contrast in other months, each shading devices show different results. Moreover model B2 and B3 has similar trend almost in all months. However B3 was higher than B2. In addition, B4 was the best reduced the solar gain, whilst B1 was the least result of the four.

On top of this overhang and louver design could perform well around the year as reduced the electricity by whole simulation, while on the other hand this design will block most of the view to environment. In fact, overhang and side fin design was not perform as well as overhang and louver design or louver design, whereas occupant might have direct contact with outside.

This study provides a clear methodology for optimizing shading design for conventional residential building in rural area with the aim of minimizing the energy consumption while maximizing daylight and occupant comfort. Exterior shading devices in residential building demonstrated good improvement both in visual environment and energy-saving strategies.

This study is a part of an on-going PhD research conducted by the first author in National Taiwan University of Science and Technology. This is performed with the support of Indonesia Endowment Fund for Education (LPDP)-Ministry of Finance, Indonesia.

References

1. IPCC Summary for Policymakers. *Summary for Policymakers.* In: *Climate Change 2014: Mitigation of Climate Change.* O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, et al. (Eds). Cambridge and New York: Cambridge University Press (2014). pp. 9–23. https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_summary-for-policymakers.pdf

2. Bureau of Energy, Ministry of Economic Affairs, Taiwan. *Energy Statistics Handbook 2016*. [Online] from https://web3.moeaboe.gov.tw/ecw/english/content/ContentDesc.aspx?menu_id=1539 (2017). [Accessed on December 2017].
3. J.J. Hwang. Renew. *Sust. Energ. Rev*, **15**,2:1392–1402 (2011). https://www.sciencedirect.com/science/article/pii/S1364032110002625
4. C.F.J. Kuo, C.H. Lin, M.W. Hsu. *Energy Policy*, **95**,C:291–303 (2016). https://econpapers.repec.org/article/eeeenepol/v_3a95_3ay_3a2016_3ai_3ac_3ap_3a291-303.htm
5. L. Baumgärtner, R.A. Krasovsky, J. Stopper, J.V. Grabe. *Energy Procedia*, **122**: 211–216 (2017). https://www.sciencedirect.com/science/article/pii/S187661021732951X
6. A.K.K. Lau, E. Salleh, C.H. Lim, M.Y. Sulaiman. *Int. J. Sust. Built Environment*, **5**, 2:387–399 (2016). https://www.sciencedirect.com/science/article/pii/S2212609016300176
7. Y. S. Chiou, Y. D. Lin, *A Portable Testbed for Integrative Daylighting Design*. Paper presented in 36th International Conference on Passive and Low Energy Architecture. (Los Angeles, United States of America, 2016). http://plea2016.uscarch.com/index.php/pleapapers/fullpapers/paper/view/1195
8. M. Konstantoglou, A. Tsangrassoulis. *Renew. Sust. Energ. Rev*, **60**:268–283 (2016). https://www.sciencedirect.com/science/article/pii/S1364032115016299**.**
9. A. A. Y. Freewan. *Solar Energy*, **102**:14–30 (2014). https://www.sciencedirect.com/science/article/pii/S0038092X14000279
10. G. Kim, H.S. Lim, T.S. Lim, L. Schaefer, J.T. Kim. *Energy and Buildings*, **46**:105–111 (2012). https://www.sciencedirect.com/science/article/pii/S0378778811005032
11. E. Elbeltagi, H. Wefki, S. Abdrabou, M. Dawood, A. Ramzy. *J. Build. Eng*, **13**:127–136 (2017). https://www.sciencedirect.com/science/article/pii/S2352710217302711
12. Y.S. Chiou, K.M. Carley, C.I. Davidson, M.P. Johnson. *Energy and Buildings*, **43**, 12: 3528–3538 (2011). https://www.sciencedirect.com/science/article/pii/S0378778811004087