Integrated Solutions for Infrastructure Development
Edited by Lau, H. H., Tang, F. E., Ng, C. K., and Singh, A.

ISBN: 978-0-9960437-3-1

NEAR ZERO ENERGY HOUSE (NZEH) DESIGN VARIABLES FOR HOUSING DEVELOPMENT

YUSUF LATIEF, MOHAMMED ALI BERAWI, LENI SUPRIADI, JADE PETROCEANY, AYU HERZANITA and ARIO BINTANG KOESALAMWARDI

Civil Engineering Dept, Universitas Indonesia, Depok, Indonesia

Housing development, as part of the economic development must be supported by energy availability in order to obtain a sustainable growth. One of the approaches to support the renewable energy promotions is designing and building energy efficient housing. However, optimal design of energy efficient buildings is facing two conflicting requirements, namely cost effective consideration and minimum environmental impact. The high costs from energy efficient building such as the Near Zero Energy House (nZEH) is due to high price of materials and equipment used, such as solar panel, insulation and other supporting materials. Indonesia is situatued at the equator and received sunlight throughout the year. Nonetheless, this potential has not been fully discovered due to the high cost of the solar generated energy technology for housing. Moreover, this technology is not integrated with the main electricity network. Thus, the objective of this study is to identify the design variables for nZEH that suit the tropical climate condition in Indonesia. Experiments and Case Study are used for the study, and the validated design variables for nZEH, which includes building orientation, PV, fenestration, and passive design, will be the basis for optimum nZEH design.

Keywords: Near Zero Energy House, Energy, Tropical climate, Indonesia.

1 INTRODUCTION

Economic development of a developing country such as Indonesia depends on energy availability in a sustainable manner that requires attention to environmental aspects. In a smaller scope as housing, energy performance of a dwelling depends on the key element of carbon dioxide emissions reduction and energy savings. In the matter of improving the energy performance of a house, nZEH is proven as a cost-effective solution to overcome climate change and increase energy security. Moreover, it can support energy conservation which could address issues due to climate change such as the increase of global temperature and the reduction of fossil fuel energy (Rattanongphisat and Rordprapat 2014). In adoption of nZEH concept, using the energy collected from the sun, enable the building to generate its own saved energy which minimizes the utilization of energy from sources outside the building.

Located in the equator and illuminated by the sun throughout the year makes Indonesia an ideal location for development of renewable energy i.e., solar energy and its implementation and application in nZEH technology. However, this potential has not been fully explored due to the high cost of solar power generation systems technology (Zhou *et al.* 2001, Evola *et al.* 2014). Accordingly, the use of solar panels on the building technology in Indonesia, is still very rare. The practical uses of solar panel technology are limited to a street lamp, or a building located in remote places far from the PLN[1] grid.

This problem also poses a contradiction since design of energy efficient buildings typically uses expensive materials and technology, which directly affects the overall cost of construction (Milajic *et al*. 2013, Panão *et al*. 2013). It requires compromise and optimization of the use of "green" technology and construction cost, so that energy-efficient building technologies affordable to society. Several studies have conducted to examine the design optimization of nZEH in sub-tropical climate to four seasons climate environment. The purpose of this study is to identify design variables for nZEH to be optimized; particularly in the tropical climate therefore it uses design variables corresponding to the condition of Indonesia, which has a tropical climate.

2 LITERATURE REVIEW

2.1 Definition nZEH

Basically, the concept of Zero Energy Building (ZEB) is a building that able to meet its energy needs from cheap, clean, easy to obtain, and renewable source. A clearer definition states a ZEB concept generates renewable energy on site as much as or even exceed its annual energy consumption. A zero energy building can be defined in several different ways, usually depending on the project objectives. Thus explains more building owners think about energy spending these days. Torcellini *et al*. (2006) introduces four different types of commonly used definitions, namely: net zero site energy, net zero source of energy, net zero energy cost, and net zero energy emissions. Meanwhile Haslam and Farrell (2014) highlighted an energy-plus buildings and buildings that consume slightly more energy than they produce are called near-zero energy buildings (nZEB).

2.2 nZEH Practice in the World

One of the NZEH designs is Ecoterra nZEH in Canada which equipped by Building-Integrated Photovoltaics (BIPV). In addition, Pearl River Tower in China implies wind turbines, radiant slabs, microturbines, ground heat pump, ventilated facades, BIPV, and natural lighting control system in its building concept. Inherit the number of floors and spacious available, efforts are made to bring the concept of Zero Energy Building (ZEB) by reducing the energy account for the use of building lighting and air conditioning system. In order to reduce the energy consumption, the building was designed by combining site orientation, shape of the building, natural lighting and automated building control systems. Moreover, in Germany there are also Canadian Solar and Green City Energy that gather the installation of solar power plants with a capacity of 1 MWp on 16 rooftops, with a total area of 17,000 square meters in the city Haertensdorf, Germany.

Various design variables for nZEH used in previous studies are as follows (Boeck *et al.* 2013): (1) Renewable Energy Technologies, namely the use of PV (a) the ratio of the panel area - roof area and (b) Directions azimuth (orientation) of PV panels; (2) The shape of the building (a) building orientation, (b) the slope of the roof; (3) building envelope that affect insulation; (4) fenestration (windows and doors) with the components of the window glazing

[1] Indonesia State-Owned Electricity Company

type, window-to-wall ratio, type window sills, window direction, internal and external shading; (5) Heating-Ventilating-Air Conditioning (HVAC) which affected Natural Ventilation and mechanical Cooling / heating; (6) Lighting.

Boeck *et al.* (2013) also conducted a study to muster 65 scientific journals that discuss about energy efficiency in housing and apartment buildings. The results of this study are used as a reference in the preliminary variables comply to this research whereas resulted in 5 groups of variables other than the use of PV panels: building shape, building envelope, fenestration, HVAC, and lighting. Additional variables, i.e., PV panel, obtained from Bucking *et al.* (2013) who studied nZEH that uses PV panels.

3 METHODOLOGY

The research strategy used are experiment and case study - due to the absence of nZEH in Indonesia. Experiments conducted assessment of 400 design variable combinations calculated manually with the assistance of EnergyPlus™ software. EnergyPlus™ is a whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption—for heating, cooling, ventilation, lighting and plug and process loads—and water use in buildings.

Variable designs which can be attributed to energy efficiency (adapted from Boeck *et al.* (2013)) are utilized in nZEH simulation, with parameters of tropical climate. The experiments conducted at the beginning of the study was the development of a house building model. Indicators of a schematic model of energy in a house is checked by EnergyPlus™ simulation using two sample models of houses – one with PV house and the other, non-PV house.

A number of 400 scenarios design variables that affect the energy buildings along with varieties of building azimuth, window-wall ratio (WWR) and glazing type were used in the experiment. The combination of design variables and its variations produce: data distribution and nZEH zone, conventional and PV house, optimal cost; the combination of design variables on the energy consumption; and the combination of design variables on cost of electricity. Therefore, the design variables that can be used and optimized, among others: (1) Renewable Energy Technologies, in the study, Photovoltaic (PV); (2) Building through the sub-variable of building orientation; (3) Fenestration (windows and doors) with subvariable window glazing type and window-to-wall ratio. These design variables may be combined with other design variables and varied into several sub-variables then used as input data in building a nZEH house model, where the software help simulate energy consumption of the building site as well as resources and NPV calculations of life cycle costs.

In addition to the experiment, a case study was conducted using Listijono's designated house in Pluit Residential House as a secondary data, an ASEAN-winning Energy Efficiency and Conservation (EE & C) Best Practice Competition in Buildings in ASEAN Energy Awards - 2014.

Pluit Residential House occupies a site area of about 250 square meters and was completed in March 2013 whereby equipped with three storeys and one flat roof for Solar cell, one cold water tank, one hot water tank, one Virtual Routing and Forwarding (VRF) Air Conditioning unit with hot water generation, three parabolas, one Pyramid meditation, two outlets voids, one sky lighting, Green roof and one Gazebo for leisure area. The total gross floor area of the building are 781 square meters designed by Aria Architect and John Budi H Listijono as its M&E Engineer (Listijono 2014).

4 RESULT AND DISCUSSION

4.1 Optimum Design Cost of nZEH

From the experiment, it was found that for optimum nZEH design costs, combination of azimuth is known to maximize the generation of electricity from the PV panel. Azimuth to intensify generation of electricity from the PV panel ranging from -10 azimuth to 10 from the North face orientation. Then, this azimuth is combined with other design variables to minimize the consumption of energy, i.e., electrical energy from air conditioning.

Variables that could minimize the use of air conditioning are WWR and glazing. Determination of the ratio of WWR to occupy the right selection type of glazing, enable minimum amount of heat energy derived from solar radiation, without lessen the natural lighting during the day (daylighting). For tropical areas such as Indonesia, WWR ranged from 15 to 20 percent believe to be enough for optimum natural lighting during the day without letting excessive intrusion the heat energy from solar radiation entering the house. Besides WWR, the choice of glazing may affect the amount of heat intensity of solar radiation to the house. Hence, to minimize the use of air conditioning for nZEH in the tropical area, a wise choice of glazing on the windows would limit the intensity of solar radiation.

4.2 nZEH Design Variable (for Tropical Climate)

Development of the building design with Near Zero Energy House (nZEH) in Indonesia is influenced by several variables. Based on the experiment, some variables which affect nZEH optimum design in Indonesia are building orientation direction, Panel Photovoltaic (PV), and fenestration. Geographically, Indonesia lies in 6^{o}North Latitude – 11^{o}South Lalitude and 95^{o}Eastern Longitude – 141^{o}Eastern Longitude, consequently this brought tropical climate to the nation. A prominent feature in the tropical climate area are high average daily temperatures and higher air humidity and relatively slow air flow for achieving thermal comfort. The use of energy in Indonesia focused on air cooling and dehumidification (reduction of air humidity) that commonly pursued using passive design to obtain a comfortable temperature inside the building (Wimmer 2013).

Moreover, the case study of Pluit Residential House exposes the passive design concept. Passive design concept acknowledge climate in Jakarta Area and natural ventilation with description of building is facing south (facing the road) where all the doors and windows are located as the openings of natural ventilation and designed from the early stage of using sky lighting to create natural ventilation to induce air speed of >0.5m/s in each floor system and day lighting system for non-air and air conditioned areas. Thus possible for having a house with natural ventilation of the temperature ranging from 24 ºC-32.2 ºC where relative humidity house ranging from 30% - 95%, to maintain the thermal comfort condition provided by air speed maintained at 0.4- 1.0m/s.

The air speed induced by this natural ventilation of sky lighting is very powerful that the curtains were blown with air speed of more than 1.0m/s even if the doors are fully opened. While the sky lighting produce day lighting in none air conditioned area, for 1st, 2nd and 3th floor respectively, it is also function to suck the hot air. With dimension of 1st and 2 nd floor void area are 4m x 5m, and the 3th floor void area is 1.5m x 5m help prevent the solar radiation from entering to the lower floor.

Other highlight to the design is the utilization of LED light that covers 98% of light. Using particular design make a big saving for having day lighting generated from the sky lighting, and two others void in this building whereby the light load in this building is only 3.4

Watt per square meter. As part of green technology, the solar PV panels contribute 25.7% of the total electric energy from the grid, therefore it is very important to monitor and maintain the performance of this solar PV Panel. Consequently, WIFI Plug installed in those 3 solar inverters to monitor and record the total electricity generated in these solar PV to keep the electric energy generated above 8 kWH/day with the average of 12 kWH/day (Listijono 2014).

Thus, from the experiments and case study, there are four design variables for nZEH that significantly suit the tropical climate and support energy efficiency, which are: building orientation (building azimuth), panel PV, fenestration dan passive design. These findings are also relevant with the studies of Wimmer (2013) and Torcellini *et al.* (2006). Firstly, to its tropical climate with high average temperatures caused by vertical positioning of the sun, Indonesia bound to have set up on building orientation toward the north 0^o to get comfortable indoor temperatures and reduce expenditure due to electricity costs for air cooling system and lighting. Secondly, for tropical countries, such as Indonesia where the sun shines all year round, a renewable energy source derived from sunlight is seen as a potential energy. Solar radiation can be used to generate electricity (Photovoltaic) for building utilities, and heating the water (Photovoltaic Thermal). Thirdly, fenestration, materials and installation also contribute to the energy channeled through the windows, doors, or skylights, together with the airflow in the window components to the means of increased energy efficiency. Last but not least, passive design is apt to be applied in tropical countries since the passive cooling system obtain a comfortable temperature (thermal comfort) in the building (Wimmer 2013, Torcellini *et al.* 2006).

5 CONCLUSION

As a result of this research by looking at experiment of modeling 400 scenarios and case study of Pluit Residential Housing that agreed upon expert validation through literature, nZEH design variables that can be used in the tropical climate are: building orientation, PV, fenestration, and passive design. Whereas the variables comply proposition of the north 0^o facing of building orientation; maintain PV Solar performances; fenetsration through WWR ranged from 15 to 20 percent; performed passive design that affirm the temperature ranging from 24 ºC-32.2 ºC, humidity house ranging from 30% - 95%, to maintain the thermal comfort condition provided that the air speed is maintained at 0.4- 1.0m/s with its natural ventilation. These variables can further be used to optimize the design NZEH in Indonesia in order to increase performance and achieve energy efficiency with optimum life cycle cost.

Acknowledgments

This paper is part of Research Grant from Ministry of Reseach, Technology and Higher Education Republic of Indonesia (Kemenristek) 2016.

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