Near zero energy house design parameter implementation in cluster housing – a case study

Y Latief¹, M A Berawi¹, L S R Supriadi¹, A B Koesalamwardi¹ and A Herzanita²

¹ Civil Engineering Department, Faculty of Engineering, Universitas Indonesia, Indonesia
² Civil Engineering Department, Faculty of Engineering, Universitas Pancasila, Indonesia

E-mail: *lsagita@eng.ui.ac.id

Abstract. The sustainable concept of housing supports a house in reducing the dependence on fossil-based energy. The environmental impact of a housing building, particularly CO₂ emissions, depends on the house overall design, including site planning, configuration, materials, construction, and operation where every aspect affected the house environmental performance. Nature has provide sufficient energy to tropical climate environment like Indonesia. Nevertheless, economically viable cluster housing is the other issue that encounter high costs housing from energy efficient building such as the Near Zero Energy House (nZEH) due to high price of materials and equipment used. The objective of the research is to understand how nZEH design parameter has been implemented and give impacts on architectural form of housing design. Methods used in this study is qualitative approach using research instruments among others: checklist, interview form and observation log book. From the case study conducted in this research, it was found that the object, the cluster design housing, are poorly incorporate the nZEH design parameter due to costly reasoning that impact to initial cost of the housing building. Among the design parameter which has been suggested are limited to passive design, fenestration, HVAC, lighting, and minor consideration to operation and maintenance.

Keywords: Design Parameter, Building Specification, Construction, Cluster, Housing

1. Introduction
As a developing country, Indonesia’s economic development depends on its energy sustainability that requires attention to environmental aspects. In a smaller scope such as housing development, shifting forward to a sustainable concept of housing entitle a house to play a significant role by reducing the dependence on fossil based energy appliances among others. Thereby, environmental impact of a housing building, particularly CO₂ emissions, depends on the house overall design, including site planning, configuration, materials, construction, and operation where every aspect affected the house environmental performance. To improve the energy performance of a house, nZEH is proven as a cost-effective solution to overcome climate change and increase energy security. Furthermore, 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. In adoption of nZEH concept, using the energy collected from the sun, it enables the building to generate its own saved energy which minimize the utilization of energy from sources outside the building [1].
Indonesia is an ideal location for development of renewable energy i.e. solar energy and its implementation and application in nZEH technology because it is located in the equator and illuminated by the sun throughout the year. Nonetheless, this potential has not been fully explored due to the high cost of solar power generation systems technology. Currently, the use of solar panels on the building technology in Indonesia, is still very rare. The practical uses of solar panel technology is limited to a street lamp, or a building located in remote places far from the PLN (Perusahaan Listrik Negara – a state owned electric company) grid [2] [3] [4].

This issue also causes a contradiction since design of energy efficient buildings typically uses expensive materials and technology, which affects the overall cost of construction. It needs a balance and optimization of the use of "green" technology and construction cost, so that energy-efficient building technologies can be affordable to society. Several studies have conducted to examine the design optimization of nZEH in sub-tropical climate to four season climate environment. Also, studies regarding the suitable design parameters for nZEH have been conducted in sub-tropical climate and the tropical climate [4] [5] [6] [7].

In order to have a comprehensive approach for optimizing the nZEH design parameters towards the lifecycle cost of a house, the implementation of the nZEH design parameters in a house should also be studied. This paper discusses the objective of the study, which is to understand how nZEH design parameter has been implemented and give impacts on architectural form of housing design, particularly in small housing development.

2. Literature review

Generally, the concept of Zero Energy Building (ZEB) is a building that is able to meet its energy needs from inexpensive, clean, easy to obtain, and renewable source. Other 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. Therefore, it explains more for the building owners to think about energy consumption. Torcellini, et al. [8] explained 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. Furthermore, Haslam and Farrell [9] stated an energy-plus buildings or buildings that consume slightly more energy than they produce are called near-zero energy buildings (nZEB). This could also be applied to housing, where the term would change to near-zero energy house (nZEH).

2.1. Examples of nZEH Practices

There are several nZEH practices throughout the world. Pearl River Tower in China adopted nZEH concept which is equipped with wind turbines, radiant slabs, microturbines, ground heat pump, ventilated facades, BIPV, and natural lighting control system in its building concept. Based on the number of floors and space available, efforts were made in this building 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. Also, one of the NZEH designs is Ecoterra nZEH in Canada which is equipped by Building-Integrated Photovoltaics (BIPV) [10]. 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. These renewable energy technologies (RET) support the implementation of ZEB concept [11].
In Indonesia, Listijono’s designated house in Pluit Residential House was 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 [12].

2.2. nZEH Design Parameters

According to Boeck et al [13], several design parameters for nZEH used in previous studies are as follows: (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 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 [13] also conducted a study to collect 65 scientific journals that discussed about energy efficiency in housing and apartment buildings. The results of this study were 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 [10] who studied nZEH that uses PV panels.

To further validate the nZEH design parameters for tropical climate, some relevant studies were used as benchmarks. Development of the building design with Near Zero Energy House (nZEH) approach in tropical climate such as Indonesia is influenced by several variables. Based on the study, some variables which affect nZEH optimum design in Indonesia are building orientation direction, Panel Photovoltaic (PV), and fenestration (windows and doors) with window glazing type and window-to-wall ratio subvariables. Geographically, Indonesia lies in 6°North Latitude – 11°South Latitude and 95°Eastern Longitude – 141°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 are commonly pursued using passive design to obtain a suitable thermal comfort inside the building [4] [7].

Furthermore, 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. 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 [12].

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 [7] and Torcellini et al [8]. 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° 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 apt to be applied in tropical countries since the passive cooling system obtain a comfortable temperature (thermal comfort) in the building [7] [8].

3. Methodology
To further understand how nZEH design parameter has been implemented and give impacts on architectural form of housing design in tropical climate, this study used case study as the methodology. A cluster housing X in Tangerang, Banten is chosen as the case study. It was chosen based on the type of housing (small cluster housing) and located in the suburban area in Banten, as one of the growing population and economic areas in JABODETABEK, Indonesia. The research instruments were checklists, interview form and observation log book. Checklists were used for comparing the housing concept from the developer and the nZEH design parameters. Interview form and observation log book were used for guiding the surveyors during interview process with the developer respondents. There were three (3) respondents that provide the data for the case study. The respondents were the Project Manager, Design Staff and Marketing Manager of cluster housing X.

4. Result and discussion
There were three main aspects that were studied and observed in the case study, which are the building specification, construction specification, and the implementation of nZEH design parameters.

4.1. Building Specification
The surface area of one house in the cluster housing X was 72m², and its building area was 54m². The house consists of one living room/family room linked directly with dining room, two bedrooms, one bathroom, one kitchen, and one roof garden. The main living area of the house is on the first floor, whereas the second floor was utilised for roof garden area. The house can be occupied by 3 – 5 persons. When designing this house, the hourly average temperature and wind velocity were not specifically measured by the architect. For further illustration, Figure 1 shows the floor plan, views, and interior views of the house in cluster housing X.
Figure 1. Floor Plan and Views of Cluster Housing X (a-f) (on-site data, 2016)
4.2. Construction Specification

Regarding the materials, cluster housing X used light bricks for its external and internal walls due to the light weight, fast installation and heat absorbent. For the external and internal doors, aluminum were used for the frame and termite-protected wooden layers were used for the panel. As for the window, the frame was made of aluminum and the panel was made of glass. The floor tiles were made of ceramics, and the ceiling was constructed from concrete tiles. Due to confidentiality, the detailed construction cost of the house cannot be acquired. However, the respondents stated that the range for the construction cost of one house were approximately between Rp 500 million – Rp 750 million.

4.3. The Implementation of nZEH Design Parameters

As for the implementation of the nZEH design parameters, the aspects that were observed on the house were as follows:

- Renewable energy technology - Photovoltaic (PV) panel: The house did not utilise any PV panel. The reason is that PV panel is still expensive, and this house is targeted for the low – medium income consumers. Therefore, design parameters such as the panel/roof ratio and panel orientation were not considered and implemented.
- Building orientation (building azimuth): This aspect is used for the house design parameter, where the house was facing west or east for receiving the optimum sunlight.
- Passive design: Regarding its shape, the house was designed using the modern minimalist concept where it can be expanded in the future (for example: constructing additional room on the second floor). In terms of complying to the nZEH design parameters, this house did not fully implement them. The roof of the house is flat (no pitch / angle), and the building materials were mostly conventional. The natural HVAC could only be utilised through the sliding door which connects the family room and the kitchen, where the air circulation can be adjusted through that door. As described in Figure 1, the sliding door uses Switchable VisionPanel technology, where the glass of the door can be switched into different level of shading and transparency, as needed by the occupants. Moreover, for the lighting aspect, the house received natural lighting from the skylight area above the kitchen, and mostly used artificial lighting.
- Fenestration: For its windows and doors, there were no additional insulation, glazing, nor internal / external shading. The window-to-wall ratios were also not specifically designed to comply the nZEH requirement. The only component that adopted nZEH design parameter was the sliding door, which adopted the shading aspect of nZEH.
- Energy monitoring: There was no specific monitoring tool for the house’s energy performance / efficiency. The only metered tool available was the standard electricity monitoring tool from the Government National Electricity Company (PLN).
- Electricity consumption: From the respondents, the total electricity consumption per month for one house in this cluster was around Rp 300.000,- to Rp 500.000,-. This is still considered as normal for small houses. However, further approach to minimize the monthly electricity cost should be considered, especially for the low-medium income families.

From the results, it was found that most of the nZEH design parameters were not implemented yet in the house. The house only focused on the passive design (lighting and natural HVAC) and the building orientation for receiving optimum sunlight. Specific technology such as PV panel (RET), fenestration design, and daily energy monitoring tool – which mostly support energy efficiency for nZEH were not installed. Hence, the energy efficiency that can be derived from the house was only from the natural lighting (mostly during the day) and air circulation. Most of the house in the cluster housing X still uses air conditioning in their rooms.

Furthermore, it was also found that the developer of cluster housing X chose only minor parts of the nZEH design parameter in the house due to economical reasons. They opined that by having some parts of the Green Building aspects in the house, it could be a value added factor from the marketing point of view. Also, due to economical reason, the developer also viewed that utilizing RET,
fenestration design and energy monitoring tool are expensive which could increase the initial cost of the house. They believed that designing, constructing and selling a nZEH house would cost more than Rp 1 billion, and this is not quite suitable for small houses such as cluster housing X.

5. Conclusion
To conclude, this study showed that the cluster design housing X in Tangerang, Banten, poorly incorporate the nZEH design parameters. The lack of implementing the nZEH design parameters were due to economical reasons, which the developer viewed that most of the design parameters need higher material costs that lead to higher initial cost of the house. Although some studies found that nZEH can save more energy and has lower operational and maintenance costs, the developer still focused on having a reasonable initial cost, hence not prioritizing the full implementation of nZEH design parameters. The case study only focused on minor aspects of the nZEH design parameters, which are limited to passive design, fenestration, HVAC, lighting, and minor consideration to operation and maintenance.

The result of this study provide important feedback for further studies on nZEH, particularly in Indonesia. This case study is one finding of a small cluster housing in a suburban area in JABODETABEK. The nZEH design parameters that were implemented in this case study can further be used for optimization in order to increase the energy performance and achieve energy efficiency with optimum life cycle cost of the similar type of house. Moreover, similar approach can be conducted to other types of housing in Indonesia.

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