Design of Net Zero Energy Building (NZEB) for Existing Building in Jakarta

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ABSTRACT: This Research is focusing to design technical and financial viability of Net Zero Energy Building (NZEB) from a study case of existing building in Jakarta, first by reduce Building’s energy consumption and employing renewable energy sources. The results showed that energy savings from implementing green building concept could reduce electricity usage by 18% and Return on Investment (ROI) 3.86 years, the utilization of the working scheme of the condenser pump to be used as a micro hydro power plant will generate Electric Power of 733.83 kW and have the potential to replace electricity supply from Grid/PLN by 26% and ROI 3.5 years, the installation of Building Integrated Photovoltaic (BIPV) has Potential to generated electricity 802,344 MWh/Year or 3% to replace electricity supply from Grid/PLN and ROI 137 Years. In general, the NZEB potential is 47% to replace electricity supply from Grid/PLN.

Keywords: Net Zero Energy, BIPV, Micro hydro, Green Building, Energy Efficiency

1. Introduction

At the current condition when the issue of energy security and environmental sustainability become a concern of many countries [1,2,3,4], buildings sector are important as they could create significant impacts on its. In Indonesia building sector consume of the primary energy almost 20% [5] This study aims to make designs for commercial buildings especially existing high-rise buildings to be as efficient as possible in energy use by retrofitting to reduce energy consumption and employing Renewable Energy Sources (RES) by utilizing the potential building heights and cooling water systems to be utilized as micro hydro plant and the application of Building Integrated Photovoltaic (BIPV) on roofs and building facades. This research uses the concept of the Net Zero Energy Building (NZEB) which has several definitions for example according European Union through Energy performance of buildings directive (EPBD) states that "nearly net zero energy buildings mean buildings with very high energy performance (very efficient) [3], the amount of energy required from the Grid is almost zero or very low than needed and can significantly generate energy from renewable energy sources (RES). The definition of NZEB can be found in various literatures [6,7,8,9]. The basic elements in definition of NZEB and their relationship are shown in figure.1. The basic elements are building system, energy grid and weighting system. In order to make a clear balance calculation for the net zero goal, a boundary need to be clarified for the building system with on-site renewable. Inside this boundary, building system consumes delivered energy, such as electricity, natural gas, from on-site renewable and energy grids, and output energy back to the grid when the REP (renewable energy power) system generates excess

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electricity. Because of different design goals, different weighting systems are chosen to calculate the net energy obtained by the entire building system. For example, building owners typically care about energy costs, so they prefer to choose a weighting system in the cost balance, rather than the energy balance. Finally, weighted demand and supply are compared to check whether the net zero balance can be achieved based on the specific technology solution. This can be considered as the operating mechanism of basic NZEB evaluation.

In addition to the literal definition, NZEB can also be defined in the form of a mathematical equation. Satori et al. discussed the criteria for NZEB definition and present a simplified equation to describe the definition, which is shown as Equation (1) [10].

\[
\text{Import energy} = \sum_i \text{delivered energy (i)} \times \text{credit (i)}
\]

(1)

\[
\text{Export Energy} = \sum_i \text{feed\_in energy (i)} \times \text{credit (i)}
\]

(2)

Where:

\(i\) = energy carrier

For NZEB, the balance between imports and exports over a period of time must be zero, or even positive, i.e. in terms of the energy produced or the emissions contained in the material must be balanced. The equation (3) is the minimum requirement for NZEB.

\[
\text{Net ZEB} = \text{export} - \text{import} \geq 0
\]

(3)

The balance can be represented graphically as in figure 2, mapping imports (energy sent from the grid to the building) on the x-axis and exports (feed-in/energy sent from the building to the grid) on the y-axis.
2. Methodology
This research is a case study of an office building in Jakarta that has two towers, each consisting of 32 floors and 3 basement floors. Data collected from January 2016 to December 2018, when they received a Greenship’s silver rating and then made efforts to achieve a platinum award. Building electricity consumption by Ventilating Air Conditioning is 51%, Lighting System is 20%, Sewage Treatment Plant is 9%, Lift is 8%, Pump is 7%, Computers and others are 5%. The research method used qualitative and quantitative data. Qualitative methods were carried out through interviews with the Building Management, utility report (electricity bills, water bills), operational expenditure, capital expenditure, literature studies, observation, and documentation. While the quantitative method aims to find relationships or explain the causes of change based on measurable facts, so the numerical data, can be observed and measured. The data used in this study are primary data and secondary data. Primary data is building planning data from the consultant building planner, GREENSHIP assessment data from GBC Indonesia, and data from direct research obtained by researchers through surveys, interviews, and field measurements. Secondary data is data collected by other parties that have been documented so that it can be used by other parties (researchers) (figure 3).

Figure 3. Research Methodology.
2.1. Analysis for Green Building Concept to reduce energy consumption
This research took a case study of an office tower in Jakarta, with the data below (table 1).

Table 1. Building Data.

| Location          | Jl. Jend. Sudirman Jakarta |
|-------------------|-----------------------------|
| Floors            | 32 floor @tower, 3 Basement |
| Total Site Area   | 3.5 hectare                |
| Gross Floor Area  | 203.195 m² (2 tower)       |
| Clean Water Supply| PDAM & Deep well            |
| Electrical Sources| PLN & Generator             |
| Building Load     | 8.305 MVA                  |
| Building Load used| 6 MW                       |

The location of the study area is clearly seen on the map figure 4 below.

Figure 4. Location and building Orientation.

Figure 5. Height and design drawings of the building.
Area on roof and envelope/facade can be seen in table 2 below.
Table 2. Roof area and building façade.

| Description         | Area (m²) |
|---------------------|-----------|
| **South Tower**     |           |
| Roof Top            | 1432.1    |
| North Facing Façade | 4050.8    |
| East Facing Façade  | 2628.1    |
| South Facing Façade | 4465.7    |
| West Facing Façade  | 4238.5    |
| **North Tower**     |           |
| Roof Top            | 1432.1    |
| North Facing Façade | 1535.7    |
| East Facing Façade  | 1266.9    |
| South Facing Façade | 1325.6    |
| West Facing Façade  | 1325.6    |

The Building received a Gold award and planned to get a Platinum award, detail points achieved can be seen in table 3.

Table 3. Greenship Ratings rating tool [13].

| Category                                      | Point | Available Point |
|-----------------------------------------------|-------|-----------------|
| **2012**                                      |       |                 |
| Appropriate Site Development                  | 8     | 16              |
| Energy Efficiency & Conservation              | 17    | 36              |
| Water Conservation                            | 19    | 20              |
| Material Resources & Cycle                    | 6     | 12              |
| Indoor Air Health & Comfort                   | 14    | 20              |
| Building & Environment Management             | 8     | 13              |
| Point Achieved                                | 72    | 117             |
| **Rating**                                    |       |                 |
| GOLD                                          |       |                 |

From table 3 above, the building credit point is 72 and received silver award [13]. The building planned to retrofit HVAC system, Building Automation, passive design, replace the less efficient light with LED and implemented energy management system [14] with the goal to achieve Platinum Award.

2.2. Analysis for Utilizing a Condenser Pump scheme to generate Hydro Plant

By extracting data from the Building Automation System (BAS) from the control metasys system by Johnson controls (figure 6).
Figure 6. Building Automation control system, *Metasys* by Johnson control

Research scheme as shown in figure 7 below

Figure 7. Micro Hydro Scheme by utilizing a condenser pump

From figure 7, hydro plan is designed to generated electricity by utilizing a condenser pump scheme which has average water flow rate 7,909 gallon per-minute (gpm) or 0.499 m$^3$/second.
2.3. Analysis for Building Integrated Photovoltaic (BIPV). Methodology to calculate implementing BIPV is using Helioscope software, helioscope software has interfaced (figure 8).

![Helioscope interface](image)

**Figure 8. Helioscope interface [15].**

Then draw roof and façade area to be installed by BIPV (figure 9).

![BIPV installation](image)

**Figure 9. Installed a BIPV on the roof area (left) & Façade area (right) [15].**

3. Result and Discussion

3.1. Green Building Concept to reduce energy consumption

In this research found that by retrofitting and implementing building concept can reduce Energy Efficiency Index (EEI) from 238.8 kWh/m²/Year to 123.65 kWh/m²/Year, increasing chiller of performances (COP) from 3.8 to 5.0 or improvement of about 25%, recycling waste water by 71%, saving electricity bill average IDR. 466,803,325.67/month and, Increased GREENSHIP Award from Gold with 72 point to Platinum Awards with 87 Points.
3.1.1. Repair / Retrofit. Physical / infrastructure improvements by retrofitting, improvements are made to improve the Energy Efficiency Index (EEI) [4], water consumption index [4] and air circulation system. Item Repair & Retrofit and its costs can be seen in table 4 below:

| Item Retrofit | Category | Cost (IDR)       |
|---------------|----------|------------------|
| Replacement of 4 Chiller Units (3 1000 TR Units and 1 Unit 500 TR) Type Screw Compressor with more energy-efficient centrifugal type | Energy Efficiency & Conservation | 16,577,000,000 |
| Improvements to the wastewater system so that it can be used for cooling tower's make up water | Water Conservation | 1,800,000,000 |
| Replacement of conventional lights with energy-efficient LEDs [6] | Energy Efficiency & Conservation | 3,250,000,000 |
| **TOTAL COST** | **Energy Efficiency & Conservation** | **21,627,000,000** |

3.1.2. Energy Efficiency Index (EEI). Result of EEI can be seen in table 5 below

| Area (m²) | kWh/Years 2014 | kWh/Years 2018 | EEI (kWh/m²/Year) 2014 | EEI (kWh/m²/Year) 2018 | Remark |
|-----------|---------------|---------------|-------------------------|-------------------------|--------|
| 203.195   | 28,203,480    | 25,125,360    | 238.8                   | 123.65                  |        |

From table 12 EEI can be reduce from 238.8 kWh/m²/year to 123 kWh/m²/year, it means building has more efficient in energy consumption.

3.1.3. Chiller Performances. Retrofit results can be seen from the performance of the chiller efficiency which can be seen in figure 10 below, from the picture it is found that the old COP chiller is 3.8 and the new COP chiller is 5.0 or there was an improvement of about 25%.

![](Figure 10. Comparison of Coefficient Of Performance (COP) Old Chiller and New Chiller.)

**Chiller** Efficiency Comparison can be seen in table 6 below, from the table it is known that the old Chiller to get a cooling of 1 Ton of Refrigeration (TR) requires energy of 1.63 kW, while for the new Chiller to get a cooling of 1 Ton of Refrigeration (TR) energy is needed at 0.89 kW, meaning that with the new chiller we get savings of around 50% compared to the old chiller.
Table 6. Chiller Efficiency Comparison.

| Chiller Plant       | Efficiency | Old Chiller (kW/TR) | New Chiller (kW/TR) |
|---------------------|------------|---------------------|---------------------|
| Chiller (A)         |            | 0.95                | 0.53                |
| Pump CHWP (B)       |            | 0.3                 | 0.15                |
| Pump CWP (C)        |            | 0.3                 | 0.15                |
| Cooling Tower (D)   |            | 0.08                | 0.04                |
| Sistem Effisiensi   |            | 1.63                | 0.89                |
| (A+B+C+D)           |            |                     |                     |

3.1.4. Waste Water Recycle and Water Balances. Recycling results of wastewater can be seen in the building water balance, where an average of 71% of waste water is reused for Make-up water cooling Tower and gardening (figure 11).

Figure 11. Building Water Balance.

3.1.5. Electricity Bill and electricity consumption after Retrofit. Electricity bills and electrical consumption can be compared before and after retrofit, electricity bills after retrofit from 2014 until 2018 can be seen in figure 12, electricity bills continue to decline due to continued retrofit of conventional lamp replacements with energy-saving lamps (LED). Researcher using 2018 electricity bill to calculate Return on Investment (ROI).

Figure 12. Trend of Electricity Consumption [left] & Electricity Bills [right].
Figure 13. Monthly Electricity Bill, Before and After Implementation Green Building Concept.

By comparing Payment of Electricity bills before and after Retrofit, we can compare it from figure 13 above, it can be seen that the difference in electricity payments = IDR. 2,832,542,581 - IDR. 2,365,739,255.33 = IDR. 466,803,325.67 / month, From Table 11 it is found that the retrofit Cost is IDR 21,627,000,000.00 so Estimated Return of Investment = (IDR 21,627,000,000 / IDR 466.803.325,67) = 46.33 months or 3.86 Years

3.1.6. GREENSHIP Rating. After retrofitting, GREENSHIP Rating increased and received the Platinum Awards with 87 Points (table 7).

Table 7. Greenship Award.

| No’s | Category                          | Years          |
|------|-----------------------------------|----------------|
|      |                                   | 2012  | Plus | 2017  |
| 1    | Appropriate Site Development      | 8     | -1   | 7     |
| 2    | Energy Efficiency & Conservation  | 17    | 13   | 30    |
| 3    | Water Conservation                | 19    | 0    | 19    |
| 4    | Material Resources & Cycle        | 6     | -1   | 5     |
| 5    | Indoor Air Health & Comfort       | 14    | 2    | 16    |
| 6    | Building & Environment Management | 8     | 2    | 10    |
|      | Point Achieved                    | 72    | 15   | 87    |
|      | Award                             | GOLD  | PLATINUM |

3.2. Utilizing a Condenser Pump scheme to generate Hydro Plant
From table 1 above the average electricity consumption in 2018 was 2,083,714.29 kWh / month or electricity payments per month on average was Rp. 2,354,609,724.57
3.2.1. Monthly Electric Power / Load Trend

3.2.1.1. Daily Electricity Load in 1 month (figure 14)

![Electricity Load in 1 month Period](image)

**Figure 14.** Daily load for 1 month of building electricity.

3.2.1.2. Daily Electricity Load on Hourly Bases in 1 Month (figure 15).

![1 January 2019 - 31 January 2019 Real Power (MW) Vs Time (h)](image)

**Figure 15.** Hourly Basis Daily load for 1 month of building electricity.
3.2.1.3. Daily Electricity Load on Hourly Bases in 24 Hours (figure 16).

![Electricity Load in 24 Hours](image)

**Figure 16.** Building electricity load for 24 hours.

3.2.2. Potential Use of VAC system water flow as a power plant

3.2.2.1. Potential Utilization. From the building data, Average Flow Rate of the condenser water system pump is 7,909 gallon per minutes (gpm) or 0.499 m³/second, the height of the 150 meter building consists of 33 floors and 3 basements, PLN Power Load is 8.3 MVA and the highest usage is 6 MVA. From equation (4) we can calculate the power to be generated.

\[
Power (P) = Flow\ Rate (Q) \times Head\ (H) \times Gravity\ (g) \times Water\ Density\ (\rho)
\]

\[
P = 0.4989 \times 150 \times 9.8 \times 1
\]

\[
P = 733,383\ kW\ or\ 0.733\ MW
\]

Based on its output capacity, Hydroelectric Power Plants (PLTA), Potential Generators can be classified as Micro Hydro Power Plants [17]. The Potential of Electrical Power from Utilizing Condenser Water Pump can be seen on Figure 16, where the highest Power can be generated on 11.00 PM and lowest Power can be generated on 22.00 PM to 03.00 AM (figure 17).

![Potential of Hydro Power Plant](image)

**Figure 17.** Potential of Power Plant from Utilizing Condenser Water Pump.
3.2.2.2. Potential Power Plants from Utilizing Condenser Water Pump to replace daily electricity consumption. Potential Power Plants from Utilizing Condenser Water Pump to replace daily electricity consumption can be seen on figure 18 and 19, which can replace the building’s power source from 15% to 40% or in average 16%.

Figure 18. Potential of the Power Plants versus Actual Electricity Consumption of Buildings

Or if in percentage

Figure 19. Percentage of Potential Generators VS Building Electricity Consumption

From the figure 18 and 19 above, the average potential utilization of the CWP pump system for micro hydro power plants can save electricity consumption by 26% or an average savings per month of Rp. 541,765,714.29 or savings every year Rp. 6,501,188,571.43
3.2.2.3. Potential Savings. Savings Potential use benchmark data for the cost of constructing a micro-hydro power plants in Indonesia is 1500 US$ / kW [21]. At 1000 kW planning costs around 1,500,000 US$ or around Rp. 22,500,000,000 (exchange rate 1 US$ = Rp. 15,000,000) So that the savings potential is obtained roughly before considering operational costs, plant efficiency, bank interest or other cost components, then: 26% x Rp. 2,354,609,724.57 = Rp. 441,765,714.29/month

Return on Investment (ROI) = \frac{22,500,000,000}{541,765,714.29} = 42 \text{ Months or 3 years 6 months}

3.3. Building Integrated Photovoltaic (BIPV)
From the simulation the results will automatically appear Single line diagram of the BIPV system to determine the specifications of the modules, inverters and panels used can be seen in figure 20 below

![Figure 20. Single line diagram BIPV system [15].](image)

3.3.1. Metric System and Electricity Estimation. The Metric System and Estimation of electricity production can be seen in figure 21-24 below.

![Figure 21. System metric [15].](image)
3.3.2. Monthly Electricity Production. Estimated monthly electricity production for one year can be seen in figure 22 below.

![Monthly Production](image)

**Figure 22.** Estimated monthly electricity production for one year [15].

3.3.3. Irradiance, module type and Electric Production for each segment in one year[16]. Solar irradiance is power per unit area (watts per square meter, W/m²), which is received from the Sun in the form of electromagnetic radiation and is measured in the wavelength range of a measuring instrument called a pyranometer. Irradiance varies from region to region. [22] Irradiance data at the study site can be seen in Figure 22 and the results can be seen in figure 23.

![Irradiance Estimation](image)

**Figure 23.** Irradiance estimation at the research location for 1 year [16].
From Figure 22, irradiance in the study site averages an average of 3.96 kWh/m²/year, while the estimated annual irradiance collector output can be seen in Figure 24 below:

![Figure 24. Output collector irradiance [15].](image)

For condition sets, component modules, and inverters used can be seen in Figure 25, while electricity production for each segment for 1 year can be seen in Figure 26 below:

![Figure 25. Condition set & component system used [15].](image)
3.3.4. Electricity Production. The conclusion from the above simulation is that the electrical power that can be produced is 94.28 MWh. Then, the technical data and DC Name plate module is 467 kWp. The total panel is 1462 with the Trinia Solar brand, TSM-PD14320. Data of Trinia Solar products, TSM-PD14320 can be seen in Figure 27 below.

![MECHANICAL DATA](image)

Figure 27. Data Product Trinia Solar, TSM-PD14320 [20]

Referring to Table 2, the building’s roof and envelope area is 23,701.1 m². From the specification data, the BIPV electricity potential that can be generated is 802,344 MWh/year or 66,862 MWh/month or about 3% of the building’s electricity consumption. From the benchmark the cost of BIPV installation [15][16][18] is US $11.3 million or around Rp 165,318,000,000. Assumption of the electric price per kWh is Rp 1500/kWh [19], electricity generated for one year is around Rp. 1,203,516,000,000.

4. Conclusion
The results showed that energy savings from implementing green building concept could reduce electricity usage by 18% and Return on Investment (ROI) 3.86 years, the utilization of the working scheme of the condenser pump to be used as a micro-hydro power plant will generate Electric Power of 733.83 kW and have the potential to replace electricity supply from Grid/PLN by 26% and ROI 3.5 years, the installation of BIPV has Potential to generated electricity 802,344 MWh/Year or 3% to replace electricity supply from Grid/PLN and ROI 137 Years. In general, the NZEB potential is 47% to
replace electricity supply from Grid/PLN. Although this research can reduce energy consumption by up to 47% but for existing building the NZEB is still difficult to achieve if only doing retrofitting and employing RES, it is recommended to improving the building's passive design, using environmentally friendly materials that can save more energy, change the behavior of building owners and occupants to be more aware of energy savings for daily activities and also support from the Indonesian government to give appreciation to the buildings that will implement NZEB.

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