Analysis in Integrated Design Potentials Achieving Nearly Zero Energy in Office Buildings in Bangkok Neighborhood

K Lohwanitchai 1 and D Jareemit 1

1 Faculty of Architecture and Planning, Thammasat University, Pathumthani, Thailand 12121

Corresponding email: non_ran@hotmail.com

Abstract. This study aims to investigate the energy-saving potentials and design approaches to move the small and medium office buildings in Bangkok neighborhood areas to become the Net-Zero Energy Building (NZEB). The envelope designs, such as increasing the material’s thermal resistance, adding shading devices, and using high energy-efficient systems, together with the electricity production from the photovoltaic cell, are applied in the studied buildings. According to the energy simulation results, with the implementation of current design techniques, the annual energy consumption of office buildings cannot reach the NZEB. However, these design approaches can enforce the maximum building’s energy-saving capability at 88 kWh/m² that is nearly the Economic Building (ECON). The maximum energy reduction occurs when improving the high thermal performance of the building’s envelope and using high energy-efficient systems. To achieve this challenging target. Future studies should account for more energy-efficient systems as well as the building’s operation schedule.

1. Introduction
In Thailand, the office building, as included in the commercial sector, consumes electricity consumption by 35 percent of Thailand’s energy consumption, after the industrial sector [1]. The rapid growth of office building from the past decades causes that energy demand has been increasing continuously. This increment of energy demand is a major contributing factor to global warming. Furthermore, a limit of natural energy sources could affect the energy security of the country in the future. With this concern, the Ministry of Energy has set the Thailand’s 20-year Energy Efficiency Development Plan (EEDP) that all the new government and private buildings, including office buildings, have to be more energy efficiency and become the NZEB by 2030 [1]. However, the design guidelines, as well as energy-saving approaches for architects and engineers to design the office buildings achieving the NZEB, is still limited.

There is a possible approach to improve the office buildings to become NZEB for hot and humid conditions. According to the reviews of previous projects [2-6], the design for NZEBs comprises two main parts: 1) decreasing building energy use, and 2) generating electricity from renewable energy resources. The decrease in building energy consumption can be done in several ways. Most studies started with passive design techniques, including building design and material selection. Those techniques are involved in architectural work. The second technique is a part of the engineering task that the higher efficient performance of mechanical ventilation and lighting systems are selected. The final approach is to manage the building operation schedule, which requires a good corporation from the building owner, building manager, and occupants. This study aims to investigate the design potential
that introduces the office building to become the zero energy in hot and humid conditions. Several approaches recommended in the previous works are applied in the building case studies to minimize the annual energy consumption. Then the potential electricity generation from renewable energy systems is implemented. The study's results can provide a position of energy consumption performance of the office buildings and a design guideline for improving the buildings being higher energy efficiency.

2. Methodology and case study buildings

Figure 1 presents the framework of this research. This study selects two different building areas of 5,000 m² (31x31m) and 15,000 m² (50x50m), which are mostly found in typical office buildings, as case study buildings. The office buildings are located in the Bangkok neighborhood areas, which both buildings are a six-story building. The building height is less than 23m due to the local regulation. The floor to floor of each building has a 3-meter height.

Based on design approaches to be the NZEB recommended in the previous works, in this study, decreasing the annual energy consumption focuses on two main approaches: 1) building's envelope design and 2) energy-efficient system design. First is to reduce the amount of heat transfer through the building envelope by increasing the thermal resistance of opaque walls (scenario A) and windows (scenario B). Then, providing shade a building to prevent the envelope directly exposed to the solar heat (scenario C). After the design approaches are applied, in scenario D, the high efficient ventilation system with a higher Energy Efficiency Ratio (EER) value and variable airflow volume (VAV) is assigned. The LED light bulb is used to minimize energy consumption from the lighting demand. It is appointed that the air conditioner of the studied buildings is operated from 8 a.m. to 5 p.m. in the weekday, while there is no operation during the weekend.

Table 1 presents the setting conditions of the baseline and proposed buildings, which include thermal properties of wall and window materials, window to wall ratio (WWR), shading device's length, air-conditioning system, and operation schedule of air conditioning units. The annual energy use in office buildings is performed via using eQuest model [7] under Bangkok weather data [8]. As mentioned above, the office buildings are in Bangkok neighborhood areas. As a consequence, the simulated buildings are not affected by surrounded tree shade and adjacent building shade.
Table 1. Design characteristics of the building envelope and air-conditioning system

| Material                      | Baseline building                                      | Proposed building                                      |
|-------------------------------|--------------------------------------------------------|--------------------------------------------------------|
| Wall construction (opaque envelope) | Metal Frame with Fiberglass Insulation (U=0.53 W/m²K) | Metal Frame with Fiberglass Insulation (U=0.48 W/m²K) + Polyisocyanurate for interior isolation (U=0.14 W/m²K) |
| Wall Construction (internal zone) | Wall type frame (U=2.28 W/m²K)                       | Wall type frame with fiberglass insulation (U=0.77 W/m²K) |
| Roof construction             | Metal Frame with 3-inch Polyurethane Insulation (U = 0.056 W/m²K) | Metal Frame with 3-inch Polyurethane Insulation (R-18, U = 0.056) + Fiberglass for Interior Insulation (U = 0.048 W/m²K) |
| Window                        | Green Laminated (U=5.52 W/m²K, VLT:0.71, SC:0.6)      | Insulated Glass (U=1.55 W/m²K, VLT:0.62, SC:0.31)     |
| Window to wall ratio (WWR)     | 80                                                     | 20                                                    |
| Shading (Length)              | 0 m                                                    | 1.5 m                                                 |

3. Results and Discussion
In the long-term, the EEDP has targeted improving the office buildings in Thailand toward a higher standard of energy-saving capability when compared to the current minimum energy consumption efficiency standard of the buildings (BEC), as shown in Table 2 [1]. To achieve the NZEB, the annual energy consumption in office building needs to below 57 kWh/m².

Table 2. Total energy consumption required for an office building under different levels of energy-saving capability [1]

| Type                        | Description                                      | Energy-saving capability (kWh/m²-year) |
|-----------------------------|--------------------------------------------------|--------------------------------------|
| Reference                   | The average value of overall annual energy consumption in buildings | 219                                  |
| BEC (Building Energy Code)  | Minimum energy consumption efficiency standard of the buildings | 171                                  |
| HEPS (High Energy Performance Standard) | The high energy efficiency standard of the various system which can be achievable by using current technologies | 141                                  |
| ECON (Economic Building)    | The target in the near future when the technologies of equipment and various systems are developed to be more energy efficient but are still cost-effective | 82                                   |
| ZEB (Zero Energy Building)  | The long-term target when the need for external energy supply to the buildings is near zero because the energy demand of such buildings is very low and there is also on-site energy generation from renewable energy | 57                                   |

Figure 2 presents the energy consumptions calculated from each design scenario as compared with that of the reference building and four energy consumption defined for higher energy performance buildings. Overall, the calculated annual energy consumption of the baseline buildings ranges from 88–153 kWh/m², which is lower than the reference as defined in the EEDP [1]. The building’s energy consumption is mostly from cooling energy use, which accounts for approximately 60 percent. The average annual energy consumption of the small office buildings is 9 percent higher than that of the medium office buildings. The annual energy consumption of the buildings with lower WWR is 11–16 percent lower than that of higher WWR. The primary energy reduction occurs when increasing the wall's thermal resistance (scenario A) for the lower WWR and using a high-performance window (scenario B) for the higher one. Another significant reduction occurs when using high-performance systems (scenario...
D). In the final renovation scenario, the annual energy consumptions in the small and medium office buildings show 88–100 kWh/m², which are nearly ECON building.

![Figure 2](image)

**Figure 2.** Calculations of annual energy consumption in small and medium office buildings when implied with different renovation scenarios

![Figure 3](image)

**Figure 3.** Percentage of energy savings from the baseline building when different renovation scenarios are applied

When considering energy-saving performance, the small office building takes more benefits from the envelope design and the system renovations than that of the medium building do. The maximum savings obtained from the final renovation scenario (scenario D) in the small building accounts for 34 percent. In comparison, the energy savings in the medium office building shows up to 27 percent (shown in figure 3). From those saving potential, the energy reduction of 18–22 percent is achieved by improving the thermal properties of the building envelope. Using high energy efficient window could considerably reduce the annual energy consumption in the buildings with WWR of 80 by up to 16 percent. At the same time, this technique provides small savings in the buildings with lower WWR. In
contrast, significant energy reduction from increasing thermal resistance of the opaque wall occurs in cases with lower WWR.

4. Conclusion
This study aims to investigate the energy-saving potentials and design strategies to improve the small and medium office buildings in Bangkok neighborhood areas to become the NZEB. Several envelope design approaches and high-performance systems, together with the electricity production from the photovoltaic cell, are applied in the studied buildings. Even improving the thermal performance of the building envelope and replacing it with high energy-efficient systems, the annual energy consumption of those office buildings are still higher than that recommended for the NZEB. However, there is potential to improve the small and medium office buildings to become higher energy performance as defined by the HEPS based on using the current technologies. In achieve this challenging goal, future studies should account for higher thermal performance windows and energy-efficient systems. Furthermore, building operation schedules should be considered in the design.

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