Building envelope renovation for net zero energy building in hot humid climate

C Boonyaputthipong

1 Assistant Professor, Faculty of Architecture, Khon Kaen University, Thailand
E-mail: bchumm@kku.ac.th

Abstract. Net Zero Energy building has become a topic that has drawn much attention from architects worldwide. Its concept is that buildings can meet all of their energy requirements from renewable sources. In Thailand, the renewable energy that is most suitable for integration into the idea of net zero energy building is photovoltaics. With government funding, the communication affairs division building, Khon Kaen University, is selected for the renovation existing building to be net zero energy building. It is successfully proved that, after one year record, the energy produces by the PVs, 22,944 kWh is more than energy consumption, 20,932 kWh. This paper focuses on envelope renovation because it is an important part of the building that can apply to other renovation project in the future. It found that the envelope renovation for Net Zero Energy Building can be separated to be two part, for energy saving and for renewable energy installation. For photovoltaic installation, it can simply install on the metal sheet roof by using metal frame with special clip. The research and renovation on the envelope from this project can apply for the future net zero energy building in Thailand.

1. Introduction
Net Zero Energy building has become a topic that has drawn much attention from architects worldwide. The idea is to design a building to generate energy for its own use. It is proposed that in Thailand, the renewable energy that is most suitable for integration into the idea of a net zero energy building is photovoltaics. Best practices suggest that the creation of a net zero energy building should start in the early stages of the design process to allow the building to utilize both energy-efficient building systems and to generate renewable energy. However, in Thailand, there is a number of existing government buildings that have been renovated for a different function other than they were originally designed. To renovate these existing buildings to become net zero buildings will be a more complicated process than to design new net zero buildings. In Thailand’s hot-humid climate, it is proposed that the existing buildings’ envelopes are the main element that have to be renovated for energy savings. Photovoltaic installations are proposed to be the most efficient method to achieve net zero energy building status. The feasibility of renovating existing government buildings for net zero energy building in Thailand need to be proven. The existing Communication Affairs Division (CAD) building, located at Khon Kaen University, was selected for the current research project. The data collected from a CAD building survey, conducted as part of this research project, was used to inform the recent CAD building renovation. This paper focuses on the building envelope renovation. For energy savings in Thailand’s hot humid climate, the envelope needs to be designed to protect the interior spaces from outside heat, while providing enough day-lighting for the building occupants visual tasks. Building envelope renovations are proposed to be viable interventions that can also be applied to other project in Thailand and elsewhere in the future.
2. Net Zero Energy Building

Ministry of Energy created Thailand’s 20 years Energy Efficiency Development Plan (2011-2030) which was aimed at increasing the energy efficiency of government and private buildings beyond the Building Energy Code (BEC) toward Net Zero Energy Building (NZEB) by 2030. The Zero Energy Building concept is the idea that buildings can meet all of their energy requirements from low-cost, locally available, non-polluting, renewable sources [1]. Medium and large scale, cost-effective, zero energy buildings are expected to be viable in the next 15-20 years. However, rapid building technology development and determined building owners and designers have made medium and large-scale buildings successful today [2].

The Communication Affairs Division building, at Khon Kaen University, was selected to be a case study for this research project. (Figure 1-2) This building currently include a cafeteria on the first floor and offices on the second floor. From the building survey conducted as a part of this research project, it was found that the building consumed 98.60 kWh/day or 35,987.70 kWh/year. To renovate this building to become a net zero energy building, the process was to reduce energy consumption in the building by 30 – 40% and then provide renewable energy for the balance of the building’s energy needs. The process for reducing the energy used in building included:

- Replaced office equipment
- Replaced air-conditioning
- Installed cooling pads for condensing units
- Renovated the building’s envelope and roof
- Replaced the lighting systems
- Installed light pipe
- Installed photovoltaics on the roof
- Initiating a growing energy awareness for the employees in the workplace

The renewable energy source for this renovation project was photovoltaics installed on the rooftop. The building survey had showed that the energy required for a whole year after reducing energy use in the building was 21,000 kWh/year. So, the 78 panels of 260 watt PVs modules were installed on the building’s roof which generated 26,000 kWh/year in electricity.

![Figure 1](image-url)
3. Building Envelope Renovation for Net Zero Energy Building

3.1. For energy saving
The building envelope is a critical element in the energy performance of any building, but it is absolutely vital to the performance of net zero energy buildings [3]. In the hot humid climate of Thailand, the building envelope is the key component to provide thermal comfort for the building. The building envelope works as both the heat protection and the heat release for the building’s interior spaces. Proper design of the building envelope can result in a dramatic reduction in energy consumption for cooling. Often, the energy used for air conditioning is the biggest part of the energy consumption for buildings in Thailand.

The transparent quality of the existing building envelope’s glass allowed thermal energy (in form of solar radiation) into the building, which impacted energy consumption for cooling. Previously, the building had a glazing area equaling approximately 40% of the total wall area, mostly faced to the south. Even though the building wall was shaded by an asbestos cement sunscreen the heat passing through the glazing area was still high. The renovation set a goal to reduce the glazing area from 146 m² to 78 m² and to increase the opaque area from 222 m² to 290 m². (Table 1)

| Orientation | Before | After |
|-------------|--------|-------|
|              | Opaque(m²) | Glazing(m²) | Total (m²) | Opaque(m²) | Glazing(m²) | Total (m²) |
| NE          | 78     | 35    | 112       | 99      | 13       | 112       |
| SE          | 56     | 16    | 72        | 59      | 13       | 72        |
| SW          | 47     | 65    | 112       | 89      | 24       | 112       |
| NW          | 41     | 31    | 72        | 44      | 28       | 72        |
| Total (m²) | 222    | 146   | 368       | 290     | 78       | 368       |
| %          | 60%    | 40%   | 100%      | 79%     | 21%      | 100%      |

The study of F. S. Westphal, M. A. Yamakawa, L. T. de Castro, 2011 [4], showed that in a hot climate the energy consumption for cooling can be decreased through the application of thermal insulation to the exterior walls. For this building, the three inches fiberglass insulation was used for the opaque walls. By decreasing the glazing area and adding three inches of insulation, the OTTV of the building...
was reduced from 39.79 W/m² to 18.95 W/m². The heat transfer through the interior space was reduced by 52% while the window-to-wall ratio (WWR) of the building was measured as 0.21.

3.2. For photovoltaics installation
PV installation in a building can occur on a building’s wall or roof. For this project, the photovoltaics were designed to be installed on the rooftop. Before the renovation, the roof of the building consisted of asbestos cement on a corrugated hip form. The PV installation in this location required a roof slope of approximately 15 degrees facing to the south. However, the roof had to be tilted along the length of the building making the roof too high to meet the 15 degree slope. Therefore, by design the roof slope has been reduced to 10 degrees facing the south-east side. (Figure 3-4)

![Figure 3](image1.png)
**Figure 3.** The building roof before the renovation

![Figure 4](image2.png)
**Figure 4.** The building roof after the renovation

Sheet metal panels with 4 inches fiberglass insulation were used for the roof material. The 78 photovoltaic panels were installed on the sheet metal roof by using metal clips with steel frames. The 0.60 m. walking space between the panels is for service and maintenance purposes. (Figure 5)
4. Conclusion
After the renovation, the CAD building became, officially, the first net zero energy among the government buildings in Thailand. The records for one year have successfully proven that the energy produced by the PVs, 22,944 kWh is more than its energy consumption, 20,932 kWh. The building envelope renovation for a Net Zero Energy Building can be separated into two parts, for energy savings and for renewable energy installation. For energy savings, the envelope materials have to be reviewed. In Thailand’s hot humid climate, the envelope needs to be designed to protect the interior spaces from outside heat, while providing enough day-lighting. The renewable energy installation can be accomplished on the building’s roof or walls. For a low-rise building in this climate, it is better to install the photovoltaic on the roof as the roof is the part of the building that receives solar radiation most of the time. Recently, the photovoltaic panel was simply installed on the sheet metal roof by using a metal frame with special clips.
This research project shows that the envelope renovation for net zero energy buildings can integrate the knowledge of architecture and engineering to achieve success. It is suggested that best practices to renovate existing buildings into net zero buildings would include discussion and knowledge sharing beginning during the early stages of design and continue through the construction process.

5. Acknowledgments
The paper is part of the Net Zero Energy Building research funded by the Energy Policy and Planning office (EPPO), Ministry of Energy, Thailand. The research team are Asst.Prof.Denpong Sudpakdee, Research Leader, and Assoc.Prof.Tanakorn Wongwuttanasatian, Co-Researcher.

6. References
[1] P. Torcellini, S. Pless, and M. Deru, 2006, Zero Energy Buildings: A Critical Look at the Definition, ACEEE Summer Study Pacific Grove, California, 14-18 August 2006.
[2] C. Yimprayoon, 2016, Review Article: Zero Energy Building, Journal of Architectural/Planning Research and Studies (JARS) 13(2), Thammasat University, Bangkok, Thailand.
[3] H., Thomas, 2013, Net Zero Energy Design: A Guide for Commercial Architecture, John Wiley & Sons, Inc., Hoboken, New Jersey.
[4] F. S. Westphal, M. A. Yamakawa, L. T. de Castro, 2011, Thermal Insulation of Building Envelope Toward Zero Energy Design in Hot-Humid Climate, Proceedings of Building Simulation 2011: 12th Conference of International Building Performance Simulation Association, Sydney, 14-16 November 2011