The Analysis of Tall Building Energy Performance by Using EDGE Application towards Net Zero Energy Building (NZEB)

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Abstract. Net Zero Energy Building (NZEB) is one of the innovative concepts for sustainable buildings because of its ability to save energy and reduce carbon emissions simultaneously. This study used a descriptive approach to review tall building data through the parameter of saving electricity by using the EDGE application. Primary data is data obtained from working drawings or detailed engineering design (DED), work plans and specifications, and budget plans. EDGE application also produced several outputs to analyze energy performance: final energy use, operational CO2 emissions, embodied energy, utility cost, cooling loads, energy savings, operational CO2 savings, cost savings, annual EPI base case, improved EPI, number of affected people, base case and improved global warming potential of refrigerants. The EDGE also analyzed the following data: building type, site location, project details, building utility data, occupational and operational information, building dimension and specification, HVAC system, fuel used, and climate data. The energy performance of the building is analyzed by using EDGE's parameters coded by EEM 01-37 that span from the windows-to-walls ratio to the use of low environmental impact refrigerant.

1 Introduction

In recent years, the concept of energy-efficient buildings has become one of the solutions to improve energy efficiency and reduce energy consumption in buildings. Net Zero Energy Building (NZEB) is one of the innovative concepts for sustainable buildings because of its ability to save energy and reduce carbon emissions simultaneously [1]. The concept of the NZEB itself is based on the principle that buildings can meet their energy needs from cheap, locally available, non-polluting and renewable sources [2]. This is because net zero design is closely related to optimizing building designs so as to minimize energy use as low as possible so that excess renewable energy can be returned to the building's electricity network. To achieve the goals of the NZEB, building systems and design strategies must be integrated based on local climatic conditions. Research results from Feng, et al. [3] show that most NZEB cases generate an annual energy consumption intensity of less than 100 kWh per floor area and some buildings even generate more energy than they consume. From the research

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results of Kristjansdottir, et al. [4], NZEB buildings in Norway also produce lower emissions than ordinary buildings, which is 5 kg CO_2e/m^2 per year. Mora, et al. [5] suggested that by using a number of low-energy consumption techniques in NZEB buildings, energy consumption in buildings can be reduced by up to 35%. Indonesia is a tropical country located on the equator with sunshine all year round, this can be a potential and a challenge in itself in developing the NZEB design. These potentials and challenges include the use of photo-voltaic (PV) panels to obtain energy, as well as the relatively high use of air conditioning which can be overcome by implementing passive design strategies to reduce heat radiation [6]. The research shows that the application of the NZEB concept can reduce the index of electricity consumption by 98.38% from 179.6 kWh/year.m^2 to 2.9 kWh/year.m^2. Research from Latif, et al. [7] themselves put forward the design variables of Net Zero Energy Housing that can be applied to tropical climates to achieve energy savings, such as: (1) facade design that does not directly point to the rising and setting sun; (2) the use of insulation materials on building envelope elements; (3) increasing the value of the window-to-wall ratio (WWR) so that natural lighting can be utilized effectively; (4) use of canopies on windows; (5) the use of film coating on window glass to reduce heat penetration in the room; (6) utilization of energy efficient lamps and equipment; and (7) the use of PV panels facing direct sunlight. These variables can be used as material for optimizing Net Zero building designs so that they can improve building performance and achieve optimal energy efficiency. NZEB achievements can also be obtained by using energy-efficient materials and building envelope designs, then applying energy generation systems with sustainable and renewable sources (EBT) [8]. According to Utami, et al. [2] renewable supply side energy technologies that can be used in the NZEB context include the use of photovoltaics, solar hot water, wind, hydropower, and biofuels.

Malang State University as a campus that cares and is environmentally conscious has taken several actions towards more sustainable development, especially in the campus area. As stated in the Development Master Plan (RIP) of the State University of Malang for 2011-2030, the main component in developing UM as a Learning University is to build a learning environment that is beautifully arranged, calm, comfortable in learning, and has a good psychological environment. conducive to learning. Apart from that, UM's policy to take environmental action is also regulated in the Decree of the Chancellor of the State University of Malang Number 15.7.23/UN32/OT/2020 concerning the 2020-2023 Environmentally Friendly Campus (Green Campus) of the State University of Malang. Therefore, several efforts to reduce energy use in the campus area have also begun to be implemented, as evidenced by the use of 56.2% of energy-saving equipment and supplies (Inverter AC, LED lights and solar lights), 50.19% of buildings that have implemented as a smart building, and the use of renewable energy such as solar power, wind, solar cell hybrid system power plants and wind turbines, to biodiesel. Therefore, through research with the title "Analysis of the Energy Use of the State University of Malang Joint Lecture Building (GKB) Using the EDGE Building App Towards a Net Zero Energy Building", an assessment of the environmental and economic impacts as well as the amount of energy savings from the State University of Malang Joint Lecture Building can be calculated, so that it can save building operational costs, as well as reduce the annual energy use of Malang State University.

2 Method

The Joint Lecture Building (GKB) State University of Malang (UM) occupies an area of 44,792 m^2 with two typical buildings: A19 and A20. The building that became the research object of this study was the A19 Joint Lecture Building, State University of Malang which has 9 floors which has function as follows: car parking areas, laboratories, lecturer rooms, and lecture halls, classrooms, reading room, library and common room, multipurpose room, seminar room, testing center and language self-access centers. The primary data are obtained by observations and interviews with building managers. Meanwhile, secondary data are used to complement existing data, such as working drawings or Detailed Engineering Design (DED), Work Plans, Requirements, and Specifications or *Rencana Kerja dan Syarat* (*RKS*), and Budget Plans or *Rencana Anggaran Biaya* (*RAB*).

The criteria observed are criteria derived from the EDGE application [9–11], which are energy saving standards and checklists contained in the EDGE application to find out opportunities and potentials for GKB UM savings in becoming Net Zero Ready buildings. These criteria are as follows: EEM01 Window to Wall Ratio (WWR); EEM02 Light Reflecting Roof; EEM03 Light Reflecting Exterior Walls; EEM04 Outdoor Shading Device; EEM05 Roof Insulation; EEM06 Ground/Hanging Floor Slab Insulation; EEM07 Green Roof; EEM08 Insulation for Exterior Walls; EEM09 Glass Savings; EEM10 Air Sheath Infiltration; EEM11 Natural Ventilation; EEM12 Ceiling Fan; EEM13 Cooling System Savings; EEM14 Variable Speed Drive; EEM15 Fresh Air Pre-Conditioning System; EEM16 Space Heating System Savings; EEM17 Space Heating Control with Thermostatic Valve; EEM18 Domestic Hot Water (DHW) System Savings; EEM19 Domestic Hot Water Pre-Heating System; EEM20 Saving Tools; EEM21 Demand Control Ventilation with CO_2 Sensor; EEM22 Economical Lighting for Indoor Areas; EEM23 Economical Lighting for Outdoor Areas; EEM24 Lighting Control; EEM25 Roof Window; EEM26 Parking Control Ventilation Demand Using CO Sensors; EEM27 Insulation for Cold Storage Liners; EEM28 Efficient Cooling for Cold Storage; EEM29 Efficient Refrigerator and Washing Machine; EEM30 Submeter for Heating and/or Cooling Systems; EEM31 Smart Meter for Electricity; EEM32 Power Factor Correction; EEM33 Renewable Energy on Site; EEM34 Additional Power Saving Measures; EEM35 Offsite Procurement of Renewable Energy; EEM36 Carbon Balancing; and EEM37 Low Impact Refrigerant.

After identifying 37 energy saving stage parameters in the EDGE application, the next stage is to evaluate energy efficiency and determine the total energy savings of the GKB Building towards NZEB. By entering building design data into the EDGE software, energy consumption and estimated energy savings can be measured. It provides insight into the potential to achieve net zero energy targets by assessing building energy demand and the building's feasibility of integrating renewable energy generation systems to offset energy demand. Meanwhile, in determining the eligibility of GKB UM to become NZEB some of the outputs from EDGE used are shown in Table 1.

Table 1. EDGE outputs for NZEB eligibility

Components	Remarks
Energy Consumption	a picture of the total energy consumed by the building such as HVAC, lighting and equipment will be generated so that the basic energy demand of the building can be known
Energy Savings	design strategies that can be selected to reduce energy consumption as well as potential energy savings and their impact on building energy performance to evaluate the feasibility of achieving NZEB targets
Renewable Energy Potential	an estimate of the renewable energy generation used on site to compare it with the building's energy consumption so that the renewable energy generation potential can be evaluated in relation to the building's suitability for achieving net zero energy
Carbon Emissions	estimates of building carbon emissions based on energy consumption and energy network emission factors so that a building's carbon footprint can be assessed against NZEB targets and can guide decisions regarding carbon reduction strategies and sustainability reports

Cost Savings	cost analysis feature that estimates the potential financial savings associated with the energy saving measures taken so that the economic feasibility and investment strategy in prioritizing NZEB goals can also be measured

In determining the suitability of GKB UM in the Net Zero Energy Building aspect itself, GKB UM must pass the EDGE Certified and EDGE Advanced requirements so that it can move towards EDGE Zero Carbon or can be said to be Net Zero Ready. EDGE Zero Carbon certification itself is still related to NZEB because it focuses on reducing and offsetting carbon emissions related to building operational energy consumption. EDGE Zero Carbon evaluates building energy efficiency measures, renewable energy integration, and carbon offset strategies to achieve a net zero carbon footprint and considers building energy consumption and associated greenhouse gas emissions. The relationship between EDGE Zero Carbon certification and NZEB is based on the concept of balancing energy consumption with renewable energy generation. Net Zero Energy buildings aim to offset their energy consumption through on-site renewable energy sources. Likewise, EDGE Zero Carbon focuses on offsetting carbon emissions associated with building energy use by implementing renewable energy systems and other carbon reduction measures.

3 Results and Discussion

Based on the results of an analysis of the EDGE energy saving parameters applied to GKB A19 UM, an energy saving result of 44.40% was obtained. These results have achieved EDGE Certified and EDGE Advanced status but have not yet fully reached the EDGE Zero Carbon standard. These significant energy savings were achieved through the implementation of efficiency strategies which included increasing thermal insulation, optimizing cooling systems, using natural lighting effectively, using passive strategies such as ventilation and integrating renewable energy sources such as solar panels on site. Although GKB A19 UM has not achieved EDGE Zero Carbon status in the EDGE scheme, the achievement of energy savings of 44.40% indicates a commitment to reducing carbon impact and increasing building energy efficiency. In the scheme to achieve EDGE Zero Carbon, it is necessary to make more extensive use of renewable energy sources.

In the context of building readiness or readiness so that it can be called Net Zero Ready based on GBC Indonesia, there are four general requirements that must be met: Energy Consumption Intensity [12,13] or *Indeks Konsumsi Energi* (IKE) standards as well as ensuring an optimal level of comfort for residents; integrate renewable energy sources on site or comply with at least one of three sustainable energy schemes; implementing a Building Monitoring System or building monitoring system that allows for continuous monitoring and control of various building systems; as well as achieving carbon-neutral status or carbon balance through the adoption of renewable energy and/or carbon offsets.

To determine IKE of GKB A19 UM, it is known that the energy consumption based on EDGE calculations is 28,393 kWh/month and the building floor area is 18,417.39 m^2. So IKE can be calculated using the following equation:

$$IKE = (total\ energy\ consumption)/(total\ floor\ area) = 28{,}393/18{,}417.39 = 1.54\ kWh/m^2.month$$

Based on the above calculation, the GKB A19 UM IKE value is 1.54 kWh/m^2.month. Based on Minister of Energy and Mineral Resources Regulation No. 13 of 2012, this value is categorized as Very Efficient, which is less than 8.5 kWh/m2/month. Comparing the energy use of the GKB A19 UM with the base case in the EDGE application, a total energy use of 20.81 kWh/m^2.year was obtained. This energy use relates to cooling components (35%), equipment (28%), ceiling fans and ventilation (3%), general equipment (3%), lighting (23%), and water pumps (7%). There are several categories that are available in the EDGE base case but are not available in buildings, such as heating, heating pump, cooling (refrigerant), heating fan, hot water and cooking categories. These aspects cannot be applied to buildings because they are influenced by a number of factors, including but not limited to the function and type of building, as well as climatic conditions at the construction site.

Based on energy use patterns in buildings, CO_2 emissions inevitably occur as a result of the energy consumption process. CO_2 emissions are a result of activities in buildings that require energy sources, such as lighting, air conditioning and other equipment operations. In the context of building planning and management, understanding the amount and sources of carbon dioxide emissions produced is important in efforts to carry out more sustainable and environmentally friendly operations.

Most CO2 emissions come from electricity use, reaching 96% of all emissions. This is in line with the fact that the use of electricity in building operations is often the main source of building energy consumption (Center for Energy Conversion Technology, 2020). Furthermore, the contribution of emissions from the use of diesel fuel is recorded at around 3%, while emissions from the cooling system only contribute around 1% of total emissions.

The main focus on emissions from electricity use indicates the need for a strategy to increase the efficiency of electricity use, including the use of energy efficient equipment and the implementation of more efficient lighting technologies. Likewise, aspects of the cooling system require special attention in efforts to optimize energy use and reduce environmental impact. The next section will explain in more detail the energy use and each aspect involved in generating CO2 emissions in buildings, as well as the energy reduction potential of each of these aspects according to the existing parameters in the EDGE application.

Cooling at GKB A19 UM is the aspect that has the greatest impact on building energy use, which is 7.36 kWh/m2/year. Recognizing the important role of cooling in buildings, an in-depth review was carried out to identify the factors that influence energy use in cooling systems and describe strategic steps that can be taken to increase efficiency and reduce environmental impact. This is done by identifying the existing energy saving parameters in the EDGE application as shown in Table 2.

Table 2. Energy saving parameters in the EDGE application

Code	**Parameter(s)**	**Implementation**		**Savings (%)**
		Implemented	**Not implemented**	
EEM01	Window-to-wall ratio (WWR)	✓		11.23
EEM02	Light reflecting roof		✓	0
EEM03	Light reflecting exterior walls	✓		0.16
EEM04	Outdoor shading devices	✓		0.19
EEM05	Roof insulation	✓		2.45
EEM06	Floor slab insulation		✓	0
EEM07	*Green Roof*		✓	0
EEM08	Exterior walls insulation	✓		0.76
EEM09	Glass savings	✓		1.97
EEM10	Air sheath infiltration	✓		0.03

Code	Parameter(s)	Implementation		Savings (%)
		Implemented	Not implemented	
EEM11	Natural ventilation	✓		12.32
EEM13	Cooling system savings	✓		-0.96
EEM14	Variable speed drive	✓		0.75
EEM20	*Economizer* (saving tools)		✓	0
EEM21	Control Ventilation with CO_2 Sensor		✓	0
EEM26	Parking Control Ventilation Demand Using CO Sensors		✓	0
Total savings				28.9

3.1 Equipment

Equipment plays a crucial role in contributing to electricity use in a building. This aspect refers to a number of devices used in a building, which are adapted to the type and function of the building itself. In the context of EDGE, especially in the GKB A19 UM building, the equipment in question is equipment that is relevant to the type of educational facilities, especially in the university environment such as lifts, STP, and other equipment. However, such equipment is not specifically regulated in terms of energy use. This is because EDGE refers to the base case as a benchmark, which includes a wide range of equipment with different characteristics of user density and hours of operation. In this scheme, energy use by equipment does not have specific provisions, but is calculated based on the influence of the EDGE base case which describes general and normal practices in the use of equipment in similar buildings. Electricity usage originating from the equipment aspect reaches 28% of total electricity usage or 5.88 kWh/m2/year.

3.2 Lighting

Lighting is also an important aspect of energy efficiency and comfort in buildings. In the context of this research, lighting refers to the use of artificial light to provide adequate lighting in buildings. Energy use for lighting alone reaches 23% of the building's electrical energy consumption or reaches 4.84 kWh/m2/year. Apart from that, there are also efforts to save electricity related to lighting, such as the use of efficient lighting devices such as in parameters EEM22 and EEM 23, namely Efficient Lighting for Internal and External Areas, and EEM24, namely Lighting Control. In the GKB A19 UM, 5-28 Watt Fluorescent TL and 5-28 Watt TL Fluorescent lamps are used which are more efficient than standard incandescent lamps and also lighting control in the form of an occupancy detection device which can be used to turn the lights on and off automatically when they are not detected. indoor movement. In this way, the use of electricity for lighting can be optimized without sacrificing the quality of lighting needed for various activities in the building. All of these efforts can reduce electrical energy needs by up to 6.84%. This is a real step in an effort to reduce energy requirements in the lighting aspect.

3.3 Water Pumps

The use of electricity by water pumps in buildings uses the base case assumption of 7% of the total energy consumption or 1.55 kWh/m2/year. Water pumps have an important role in supporting various systems and facilities in buildings, such as cooling systems and clean water systems. In addition, several aspects also affect the use of electrical energy by water pumps in EDGE applications but are not discussed in this study such as WEM04 Efficient WC for Toilets, WEM07 Water Saving Urinal, WEM10 Water Saving Pre-Rinse Spray Valves for Kitchens, and WEM15 Processing Systems and Waste Water Recycling. In an effort to save energy use for water pumps, the Variable Speed Drive (VSD) principle is applied to the existing pumps in plumbing work, as well as other facilities at GKB A19 UM. Through the use of VSD technology in water pumps, GKB A19 UM shows a commitment to optimizing energy use and reducing unnecessary waste. Thus, the building not only reduces energy consumption, but also makes a positive contribution to environmental sustainability.

3.4 General Equipment

General equipment in the EDGE application uses 3% electricity or 0.59 kWh/m2/year according to the EDGE base case. The general equipment referred to is the load from the plug and other equipment such as computers, printers, LCDs and other small electronic equipment. Even though its contribution is lower than other aspects such as cooling or lighting systems, the use of energy by public equipment still has an impact on the total energy consumption of a building. Therefore, efficiency strategies such as selecting energy-efficient equipment, managing usage, and user awareness in turning off devices that are not in use can help reduce the energy consumption of public equipment.

Based on the calculation results from the EDGE application, GKB UM A19 has passed EDGE Certified and achieved EDGE Advanced with an energy efficiency of 45.37%. Therefore, according to EDGE, GKB A19 UM can be called a Zero Carbon Ready building because it has achieved EDGE Advanced status as shown in Figure 1.

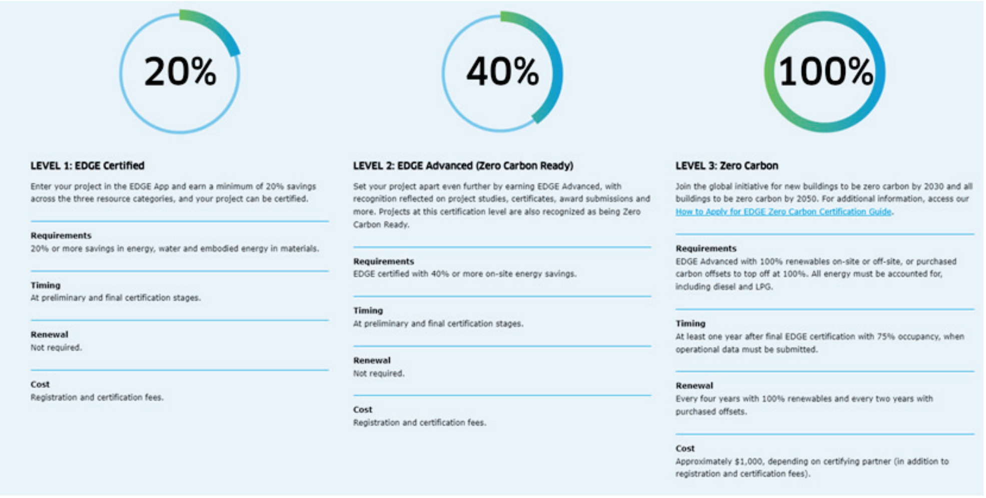

Fig. 1. Zero carbon ready level for GKB building

4 Conclusion

Even though it has obtained Zero Carbon Ready status in the EDGE application, GKB A19 UM does not yet meet the requirements to obtain Net Zero Ready status in GBC Indonesia Net Zero Healthy. This is because the new GKB A19 UM meets 3 of the 4 Net Zero Healthy requirements, where there is no control system such as the Building Monitoring System or Building Automation System that has been implemented in buildings. The implementation of this system is expected to provide the ability to automatically monitor, control and manage various aspects of buildings, including energy use, lighting, room temperature, and so on. Thus, while it has achieved significant strides in reducing carbon emissions, the next step is to integrate more advanced monitoring technologies to achieve a more comprehensive Net Zero Ready status.

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