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The effect of baseline establishment on energy savings estimate in green building certification

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Abstract. Recently, increasing energy consumption and CO_2 emissions buildings and construction together are accounted globally for 36% and 37%, respectively. This situation implies that buildings consume over one-third of energy demand and emitter CO_2 globally. Hence, energy-efficient practices were applied in green building certification to reduce energy consumption and CO_2 emission. Each green building certification follows the energy baseline created to take a step further for better future equipped energy end-use. This research objective explains the comparison of different energy baselines referring to GBCI (Green Building Council Indonesia) and ASHRAE standards. Eight buildings using different energy baselines were observed in this research. By integrating energy-efficient practices in green building certification, three energy savings methods were used to calculate different energy baselines, specifically EnergyPlus simulation, worksheet calculation, and EDGE simulation. Through the energy savings method, thus outcome energy savings estimate was obtained. The energy savings estimate in the boxplot graph showed GBCI baseline results in huge savings compared to ASHRAE baseline.

1. Introduction

The emission of CO_2 gas and the large use of energy in the third industrial revolution cannot be avoided due to the cycle of human life. CO_2 gas emissions that cause climate change and global warming have an impact on the environment. For the last nine years, each year, the world emits CO_2 gas for nearly 35 billion tons and will pump out more in the next years. That’s 50% more than the year 2000 and almost three times as much as 50 years age [1-2]. Energy use is significantly linked to economic growth as well as environmental impacts, particularly global warming. It was found that the largest source of CO_2 emissions is obtained by the building sector globally. In 2020, energy consumption and CO_2 emission buildings and construction together accounted for 36% and 37%, respectively [3-5]. Most of the energy spent in the building was used for lights, HVAC systems, and other electronic equipment like washing machines, electric stoves, and so on, according to its percentage. This situation might increase in the

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next twenty years. With the advancement of technologies and engineering, it is possible to cut down CO_2 emissions and energy consumption in the buildings.

To reduce CO_2 emissions and energy consumption, an implementation energy-efficient practices of green building certification used in buildings. Green building certification is achieving a high-performance building by significantly measurable performance in energy savings, water, and other resources, according to the Indonesian Government Regulation of Minister of Public Works and Public Housing Number 02/PRT/M/2015. Green building and high-performance building terms correspond to each other in terms of energy-efficient practices. Meanwhile, according to Pieter de Wilde, a high-performance building is a concept that allows to compare user needs with behavior of a specific building, or, in other words, a concept that allows to quantify how well a building fulfils its functions [6-7]. For each green building certification has its own baseline and energy code in every country.

The type of green building certification used in other countries can vary depending on the country's specific environmental and sustainability goals. However, there are some general differences between LEED and other green building certifications. Scope: Leadership in Energy and Environmental Design (LEED) is a comprehensive green building certification that addresses a wide range of environmental and sustainability factors, including energy efficiency, water conservation, materials selection, indoor air quality, and site selection. Other green building certifications may focus on specific areas, such as energy efficiency or water conservation [8-9].

Scorecard: LEED uses a point-based system to assess a building's environmental performance. Buildings earn points for meeting certain criteria, and the number of points earned determines the level of certification. Other green building certifications may use a different scoring system, or they may not use a scoring system at all. Regional differences: LEED is a global certification program, but there are some regional variations in the criteria that must be met in order to achieve certification. For example, the LEED Canada Green Building Rating System has some additional requirements that are specific to the Canadian climate and environment.

In this research, eight buildings located in big cities of Indonesia are selected for the research. By implementing GREENSHIP, a GBCI green building certification, three methods were used by EnergyPlus simulation, worksheet calculation, and EDGE (Excellence in Design For Greater Efficiencies) simulation. These energy efficiency and conservation methods are used to calculate energy savings estimates in percentage [10]. Energy savings estimates were obtained from energy use intensity difference between baseline and design. Each baseline referred to the standards, namely GBCI and ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) [3, 11]. Different energy efficiency and conservation methods were used and break down the result of energy savings estimates to the standard baselines of GBCI and ASHRAE.

2. Method

This research consists of three energy efficiency and conservation methods. The three methods are the EnergyPlus simulation method, using worksheet calculations, and EDGE simulation [12]. The EnergyPlus simulation method and the worksheet calculation method will be used in certain scenarios. Except the EDGE simulation method because the baseline in the EDGE simulation cannot be changed [13].

There are six scenarios in this research material. Scenarios were created to find energy savings estimates between baselines referring to the GBCI and ASHRAE standards. Scenarios were also created to find out how using different baseline models could yield very different savings results and it is also common practice in the industry to choose a practical model [14-15]. The energy baseline can act as a reference point for researchers or building designers to understand the energy consumption behavior of buildings. The baseline can be used to determine potential energy consumption savings and energy system fault diagnostics [16].

Table 1 describes each scenario used in the research materials. Each case has different criteria. For example, in case 1, the proposed design must have criteria below the GBCI and ASHRAE baseline standards (case 1 is used as a reference point for the difference between other cases to obtain energy savings estimates). Examples of criteria are number of occupants in a building, HVAC system, OTTV value, lighting, and others. Each case has an energy use intensity (EUI) value in units of $kWh/m^2/year$. Case 1 becomes a reference point for achieving savings [5, 14]. Savings are obtained from the difference between energy use intensity value of case 1 with other cases in percentage units. The following calculation of savings in detail can be seen in Equation 1 and Equation 2.

$$EUI_{difference} = EUI_{case\ nth} - EUI_{case\ 1} \tag{1}$$

$$\%\ Energy\ Savings = \frac{EUI_{difference}}{EUI_{case\ 1}} \times 100\% \tag{2}$$

Where case nth is case 2, case 3, and so on.

Table 1. Every Description of Scenarios

Scenarios	**Description**
Case 1 (*Reference Point*)	The OTTV in this case must be less than 35 W/m^2 and other parameters should not exceed the GBCI and ASHRAE criteria.
Case 2 (GBCI *Baseline*)	The OTTV in this case must be 35 W/m^2 and other parameters follow the GBCI criteria
Case 3 (*Modified* GBCI *Baseline*)	The OTTV in this case must be less than 35 W/m^2 and other parameters follow the GBCI criteria. Specifically, the number of occupants is the same as case 2 and the fresh air flow rate is the same as case 1
Case 4 (ASHRAE 90.1 *Baseline*)	The OTTV in this case is close to 45 W/m^2 and other parameters follow the ASHRAE 90.1 criteria
Case 5 (*Modified* ASHRAE 90.1 *Baseline*)	The OTTV in this case is designed at 45 W/m^2 and other parameters follow the ASHRAE 90.1 criteria
Case 6 (*Modified* GBCI *Baseline*)	This case refers to case 3, but the OTTV is set to 45 W/m^2

Each case has a different cooling load, HVAC system and criteria. All buildings WWR (window-to-wall ratio) were set to 40%. Table 2 and Table 3 describe the differences in each case.

Table 2. Description of Cooling Load Difference for Each Case

	OTTV (W/m^2)	**Occupant (m^2/person)**	**Outdoor Intake (L/s/person)**	**Lighting (W/m^2)**	**Plug Load (W/m^2)**
Case 1	< 35	15	7.0	5.5	8
Case 2	35	10	5.5	12	10
Case 3	≤ 35	15	7.0	12	10
Case 4	< 45	20	8.5	8.8	8
Case 5	45	20	8.5	8.8	8
Case 6	45	15	7.0	12	10

Table 3. Description of Different HVAC Systems for Each Case

	AHU Total Static Pressure (Pa)	**Head pump for Chilled Water Pump (m)**	**CHWP Pump Efficiency (%)**	**Head pump for Condenser Water Pump (m)**	**CWP Pump Efficiency (%)**
Case 1	294	19	70	14	70
Case 2	490	46	70	23	70
Case 3	490	46	70	23	70
Case 4	147	23	65	18	60
Case 5	147	23	65	18	60
Case 6	490	46	70	23	70

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2.1. Selection Building

Eight buildings were selected for this analysis. These eight buildings represent original buildings located in several big cities in Indonesia. These types of buildings are apartments and offices. This eight buildings model were based on a typical floor plan for office buildings and apartments. The floor plan may differ from the original building. For the purposes of this research, the difference in room plan/layout between the model and the original building can be ignored. The building model can be seen in Figures 1 to 8 with a description of each building in Table 4.

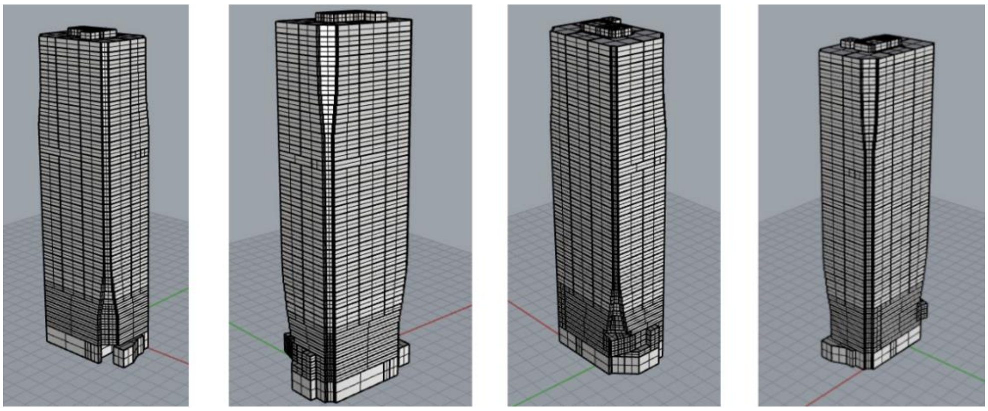

Figure 1. Building A

Figures 1. shows Commercial buildings: Commercial buildings account for a significant portion of global energy consumption. Energy-efficient commercial buildings can save money on energy costs, reduce their environmental impact, and improve the comfort and productivity of their occupants. Compare with Figure 2 whisc represent the Residential buildings: Residential buildings also consume a significant amount of energy. Energy-efficient residential buildings can save money on energy costs, reduce their environmental impact, and improve the comfort of their occupants.

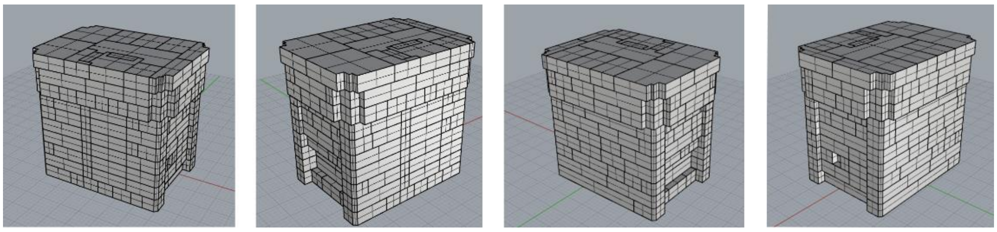

Figure 2. Building B

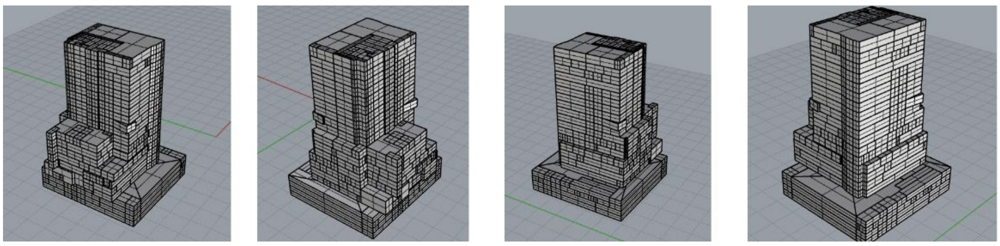

Figure 3. Building C

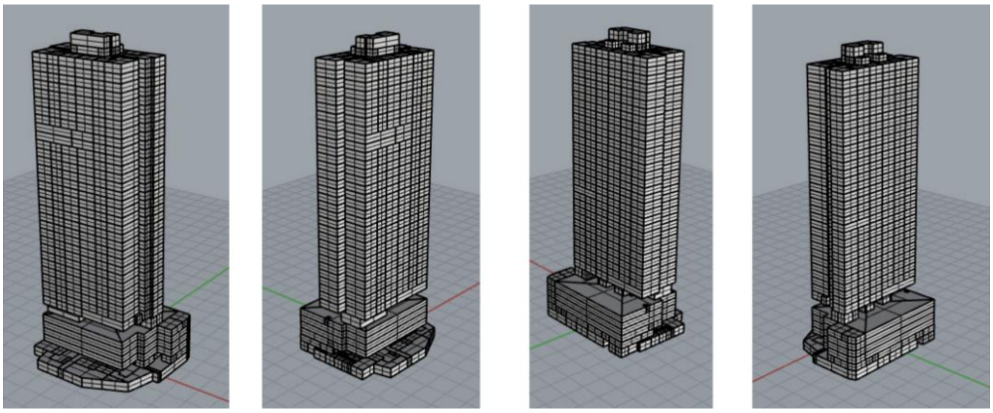

Figure 4. Building D

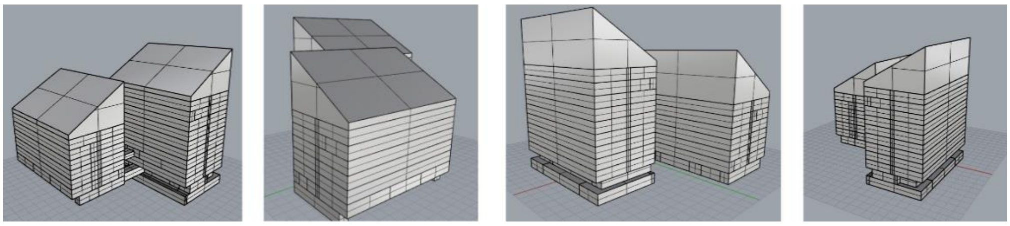

Figure 5. Building E

Government buildings (Figures 3 and 4): Large, complex government buildings are attractive targets for energy efficiency improvements. Government buildings that are energy-efficient save money, lessen their environmental effect, and inspire others. Add figures 5 last. Educational buildings: high-population buildings are attractive targets for energy efficiency upgrades. Energy-efficient schools save money, minimise their environmental impact, and make learning healthier and more comfortable for students and staff.

Table 4 lists various energy-saving strategies for these structures. Energy-efficient lighting installation: This is one of the best strategies to save construction energy. Improving insulation reduces winter heat loss and summer heat gain. Refrigerators, washers, and air conditioners should be more efficient. Install solar panels to generate power on-site and reduce grid use. Natural ventilation reduces summer air conditioning needs. Building owners and operators may reduce energy consumption and improve sustainability by implementing these and other energy-saving measures.

Table 4. Description of Each Building

Description	Unit	Building A	Building B	Building C	Building D	Building E	Building F	Building G	Building H	Formula
Outdoor Temp. (Dry bulb)	ºC DB	33	33	33	33	33	33	33	33	SNI Data
Outdoor Relative Humidity	%	74	74	74	74	74	74	74	74	SNI Data
Indoor Temp. (Dry bulb)	ºC DB	25	25	25	25	25	25	25	25	Design
Indoor Relative Humidity	%	60	60	60	60	60	60	60	60	Design
Building Floor Area / Roof Area	m²	2,016.37	967.00	1,139.35	975.88	3,938.53	11,206.34	73,010.32	5,988.21	L x W
Number of Floors		44	9	38	17	17	10	40	15	Design
Floor to Floor	m	4.00	3.40	3.50	4.00	4.40	5.00	6.00	4.00	Design
Total Gross floor area (GFA)	m²	85,794.81	8,105.68	45,544.83	32,357.16	94,155.60	40,845.42	141,008.24	12,373.29	(5) x (6)
Service Area	m²	32,333.78	2,713.18	17,161.19	17,065.60	25,027.25	6,420.79	26,559.06	3,613.75	Measured from floor plan
Nett Lettable Area (NLA)	m²	53,461.03	5,392.50	28,383.65	15,291.56	69,128.35	34,424.63	114,449.18	8,759.54	(8) - (9)
Gross Surface Area of Facade	m²	33,490.65	4,139.43	19,981.91	12,729.19	48,890.45	16,115.55	88,769.82	10,032.32	Area x (6) x (7)
Total Hours/Year	Hour	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	365 days x 24 hours
Operating Hour	Hours	10	10	10	10	10	10	10	10	8 AM - 6 PM
AC Hours / Week	Hour / Week	50	50	50	50	50	50	50	50	(13) x 5 days
AC Hours / Year	Hour / Year	2,600	2,600	2,600	2,600	2,600	2,600	2,600	2,600	(14) x 52 weeks
Non AC Hours / Year	Hour / Year	6,160	6,160	6,160	6,160	6,160	6,160	6,160	6,160	(12) - (15)

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3. Result and Discussion

3.1. Energy Savings Estimates Calculation Results

After all methods of energy efficiency and conservation methods have been carried out, with the EnergyPlus simulation method, the worksheet method, and the EDGE simulation, the results of the comparison of the energy savings estimates can be presented in the form of boxplot diagrams in Figure 6. This figure explain the comparison of the energy savings estimates with EnergyPlus simulation method, worksheet method, and EDGE simulation.

Case A shows the difference in energy savings from case 2 and case 1 (these cases can be seen in Table 1). Case B also shows the difference in energy savings from case 3 and case 1, and so on. The explanation of case A, case B, case C, case D, and case E can be seen in Table 5. In one dataset, each case consists of a collection of energy saving percentages in eight buildings. The percentage of energy savings estimates was obtained from the difference in EUI in various cases (which this percentage is obtained from Equations 1 and 2).

Table 5. Description of Case Names on the Diagram

	EUI Difference
Case A (GBCI *Baseline*)	Case 2 – Case 1
Case B (*Modified* GBCI *Baseline*)	Case 3 – Case 1
Case C (ASHRAE 90.1 *Baseline*)	Case 4 – Case 1
Case D (*Modified* ASHRAE 90.1 *Baseline*)	Case 5 – Case 1
Case E (*Modified* GBCI *Baseline*)	Case 6 – Case 1

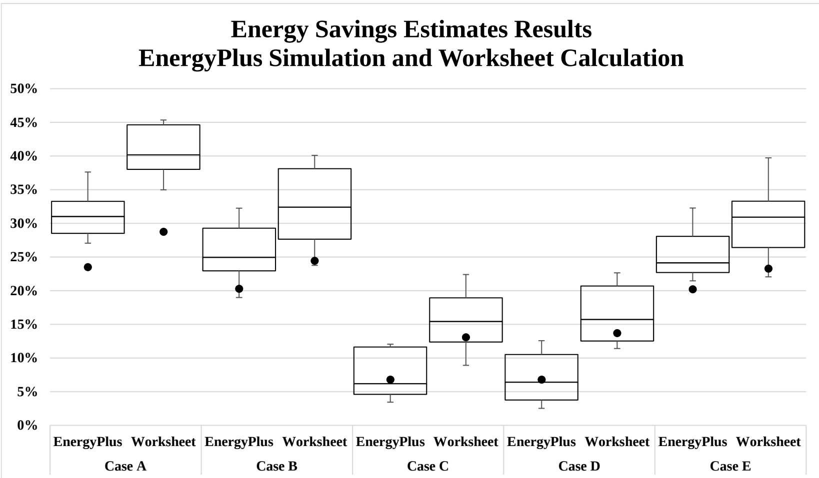

Figure 6. Energy Savings Estimates Results Boxplot side-by-side EnergyPlus Simulation and Worksheet Calculation

Figure 6 shows a box plot showing building-wide savings. Boxplot graphs show data dispersion and symmetry. Figure 6 shows 50% of boxes between the first and third quartiles. Each box has a median line. Long lines down and up (whisker bottom and whisker top) represent the lowest 25% and top 25% distribution. Each box's black mark shows the overall savings divided by all buildings' EUI baseline value.

Figure 6 illustrates building-wide average savings for each situation. Each scenario has a considerably different median value, indicating distinct savings. Case A (GBCI baseline) saved the most. Case C (ASHRAE 90.1 baseline) saved the least. Each box indicates the average savings divided by the total EUI baseline value baseline of all buildings. Case A scored highest while case C scored lowest. Because EDGE simulation cannot vary the baseline, Figure 6 presents just one boxplot for average savings.

Figure 6 indicates that baseline affects building energy usage. The GBCI baseline uses more energy than the ASHRAE baseline for the eight research buildings. Then EnergyPlus simulation, worksheet calculation, and EDGE simulation prove that they can calculate building load. Figure 6 shows that EnergyPlus simulation and worksheet computation are similar. The comparison of energy savings estimates calculations may also assist explain how the three strategies reduce building energy consumption.

3.2. Analysis of Energy Savings Estimates Comparison

The final aim of this research was to investigate the effect of different baselines. Each of these cases refers to the standard baseline, namely GBCI and ASHRAE. The explanation figures above can be said in general terms that with the use of energy in buildings that refer to different baselines, it relies on the baseline used by the building. Along with this, the baseline GBCI resulted in the largest savings compared to the baseline ASHRAE. This is because the energy system configuration used by the GBCI baseline is larger than the ASHRAE baseline. In general, the largest energy consumption in buildings is the HVAC system. If referring to Table 3, the standard HVAC system configuration at the baseline GBCI is greater than the baseline ASHRAE, although it has a pump efficiency greater than the baseline ASHRAE.

4. Conclusion

It can be concluded that the comparison methods for energy savings estimates with EnergyPlus simulation, worksheet calculations and EDGE simulation that the baseline GBCI and ASHRAE baseline have different energy systems, it is not surprising that the baseline GBCI resulted in large savings compared to the baseline ASHRAE. This is because the configuration in the energy system that the GBCI standard baseline has are greater than the ASHRAE standard baseline.

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