Optimization of Energy Efficiency and Conservation in Green Building Design Using Duelist, Killer-Whale and Rain-Water Algorithms

T R Biyanto*[1], Matradji[1], M N Syamsi[1], H Y Fibrianto[2], N Afdanny[1], A H Rahman[1], K S Gunawan[1], J A D Pratama[1], A Malwindasari[1], A I Abdillah[1], T N Bethiana[1] and Y A Putra[1]

[1] Department of Engineering Physics, Institut Teknologi Sepuluh Nopember Surabaya, Surabaya 60111 East java, Indonesia
[2] Department of Industrial Engineering, Pusan National University, South Korea

*Email: trb@ep.its.ac.id; trbiyanto@gmail.com

Abstract. The development of green building has been growing in both design and quality. The development of green building was limited by the issue of expensive investment. Actually, green building can reduce the energy usage inside the building especially in utilization of cooling system. External load plays major role in reducing the usage of cooling system. External load is affected by type of wall sheathing, glass and roof. The proper selection of wall, type of glass and roof material are very important to reduce external load. Hence, the optimization of energy efficiency and conservation in green building design is required. Since this optimization consist of integer and non-linear equations, this problem falls into Mixed-Integer-Non-Linear-Programming (MINLP) that required global optimization technique such as stochastic optimization algorithms. In this paper the optimized variables i.e. type of glass and roof were chosen using Duelist, Killer-Whale and Rain-Water Algorithms to obtain the optimum energy and considering the minimal investment. The optimization results exhibited the single glass Planibel-G with the 3.2 mm thickness and glass wool insulation provided maximum ROI of 36.8486%, EUI reduction of 54 kWh/m^2·year, CO_2 emission reduction of 486.8971 tons/year and reduce investment of 4,078,905,465 IDR.

Keywords: Green Building, Mixed-Integer-Non-Linear-Programming, Duelist Algorithm, Killer-Whale Algorithm, Rain-Water Algorithm

1. Introduction

The development in the field of building construction grows faster in terms of both design and quality of the building. Currently, most buildings are designed based on green building requirement. In the United States, investors obtain the opportunities of green building for a long-term investment. It's due to green building operational costs are more efficient than conventional buildings [1].

In Indonesia, the development of green building has been endorsed by the Green Building Council Indonesia (GBCI). GBCI has assessment standards called Greenship rating [2]. The highest point in Greenship rating is Energy Efficiency and Conservation (EEC). According to Allen, et al. [3], improving energy efficiency in buildings can reduce the serious pollutions such as solid and liquid waste as well as CO_2 emission reduction that affects human health. The highest energy consumption is used to serve the electrical demand in office building. Hartungi and Jiang [4], this type of the building consume huge energy compared to other type of buildings. The amount of energy used in office buildings are used for the cooling system of the building. Uribe, et al. [5], the external load is a major disturbance in maintaining the temperature and humidity of the building. External load is influenced by the value of Overall Thermal Transfer Value (OTTV) and Roof Thermal Transfer Value (RTTV).

The value of OTTV is influenced by the type of glass and walls. Specifications of glass types that affect the value of the cooling load is the Shading Coefficient (SC) and Light Transmittance (LT) of the glass. Value of SC affects the heat radiation of sunlight in OTTV calculation. The value of SC is proportional with the value of OTTV. According to Yik, et al. [6], finally it will reduce the energy consumption in the cooling system. Another specification of glass is LT. If the value of LT increases, then the daylight transmit to inside the building will increase due to the decreasing of artificial lighting energy consumption [7]. In addition, the value of LT on glass specification is proportional to the value of SC. If the value of LT increases, then the value of SC will increase. Although the lighting load decreases, the increasing of SC will increase external heat load. It shows the external heat load and heat load due to lighting SC and LT values on glass are non-linear. In addition, the specification of glass and the price have wide range in the market. Thus, the amount of glass investment cost related to glass specification is complex.

As mentioned before, the amount of external load is also influenced by type of roof. Bojic, et al. [8], the utilization of insulation inside the roof can be reduce the external load through the roof. Consequently, the additional cost is required due to the effort to reduce OTTV and RTTV. Finally, energy efficiency and conservation that promise higher profit or saving required higher investment as capital cost. Hence, optimization of return on investment (ROI) that consider saving and investment cost is required. On the other hand, targeted EEC point to reach certain level of Greenship is required extra investment. Since these optimized variables i.e. the type of glass is non-linear and the present of insulation in the roof is an integer, hence, the optimization problem is classified as Mixed Integer Non-Linear Programming (MINLP). Venkataraman [9], the suitable algorithm to solve MINLP problems is stochastic optimization algorithm such as Duelist, Killer-Whale and Rain-Water Algorithms due to those capability to obtain the global optimum solution.

2. Literature Review

Eighty percent of modern human activities are performed inside the building. These activities require energy, water supplies, and also produce waste materials such as solid, liquid and gas wastes that affect to planet sustainability. This impact cannot be avoided but rather be mitigated to be minimized. Moreover, green building concern to minimize the utilization of material by minimizing the waste of construction material and maximizing the use of green material that can be recycled and available near the building under construction [2]. Green building has contributed to minimize global warming by utilization of renewable energy, optimization of energy consumption and air vent [10].

2.1 Greenship Rating

Greenship rating is a GBCI standard to assess the quality of green building for certification purpose. There are 6 categories namely Appropriate Site Development (17 points), Energy Efficiency and Conservation (26 points), Water Conservation (21 points), Material Resources and Cycle (14 points), Indoor Health and Comfort (10 points), and Building and Environment Management (13 points). Refer to those categories, the EEC has the biggest point in Greenship rating. The EEC category, contain some criteria as shown in table 1 [2].

Table 1. Detail points in EEC

Criteria	Point
Electrical Sub Metering	Prerequisite
OTTV Calculation	Prerequisite
Energy Efficiency Calculation	20
Natural Lighting	4
Ventilation	1
Climate Change Impact	1
On Site Renewable Energy (Bonus)	5

Source: GBCI, 2013

In the EEC category, there are three main calculations namely OTTV calculation, simulation or calculation of natural lighting and artificial lighting, and the calculation of energy consumption. Refer to SNI 03-6389-2011, the calculation of OTTV can be described in the following equation:

$$OTTV = \alpha[U_W \; x \; (1 - WWR)] \; x \; TDek + U_f \; x \; WWR \; x \; \Delta T + SC \; x \; WWR \; x \; SF \quad (1)$$

Where $OTTV$ is the building envelope in one direction (W/m^2), α is heat absorption, U_w is thermal transmittance of opaque wall (W/m^2·K), WWR is window to wall ratio, $TDek$ is equivalent temperature difference (K), U_f is thermal transmittance of glass (W/m^2·K), ΔT is temperature difference (K), SC is shading coefficient of glass and SF is solar factor for vertical surface (W/m^2). Natural and artificial lighting calculations are performed using DIALux software. Calculation of building energy efficiency using GBCI standards is performed by comparing the baseline and design data [9]. Baseline data is the reference data that available in ISO/ASHRAE/GBCI standards. Meanwhile, the design data is building target data that is used by architects in planning of the building.

2.2 Cost of Investment

One of the purposes of calculating the energy consumption in green building is to obtain the maximum points in Greenship rating by minimizing the cost of investment. Analysis of investment cost in green building is performed by calculating the cost of building baseline investment and cost of building design investment where cost of building baseline investment is cost of investment that is calculated using the reference data of the building with a default value ISO/ASHRAE/GBCI standards. Meanwhile, the cost of building design investment is obtained from the cost of the investment as consequent of targeted EEC point. In general, the calculation of baseline cost of EEC investment is shown in the following equation.

$$C_{EEC\,B} = C_{glass} + C_{AC\,System} + C_{lamp} \quad (2)$$

Where $C_{EEC\,B}$ is cost of EEC baseline investment (IDR), C_{glass} is cost of glass investment (IDR), $C_{AC\,System}$ is cost of cooling system investment (IDR), and C_{lamp} is cost of lamp investment (IDR). While the calculation of cost of EEC investment on green building design is shown in the following calculations.

$$C_{EEC\,D} = C_{glass} + C_{AC\,System} + C_{lamp} + C_{ESM} + C_{lux\,sensor} \quad (3)$$

Where $C_{EEC\,D}$ is cost of EEC design investment (IDR), C_{lamp} is cost of lamp investment (IDR), C_{ESM} is cost of electrical sub metering investment (IDR) and $C_{lux\,sensor}$ is cost of lux sensor investment (IDR). It's also necessary to determine the cost of extra investment that is calculated from cost of baseline investment minus cost of design investment as shown in the following equation.

$$Cost\ of\ Extra\ investment = C_{EEC\,D} - C_{EEC\,B} + C_{other} \quad (4)$$

Where C_{other} is cost of extra investment of other green building category (IDR). Cost of extra investment of other green building categories are calculated using the following equation.

$$C_{other} = C_{ASD} + C_{MRC} + C_{WAC} + C_{IHC} + C_{BEM} \quad (5)$$

Where C_{ASD} is ASD category cost of investment (IDR), C_{MRC} is MRC category cost of investment (IDR), C_{WAC} is WAC category cost of investment (IDR), C_{IHC} is IHC category cost of investment (IDR) and C_{BEM} is BEM category cost of investment (IDR). The implementation of green building concept will be reduced the energy consumption compare to the baseline building. Reduce of energy consumption will increase the saving over the time. The amount of saving will be equal with extra investment at the certain time. It called return of investment (ROI). ROI calculation is shown in the following equation.

$$\text{ROI} = \frac{\text{Saving}}{\text{Extra Investment Cost}}\ x\ 100\% \quad (6)$$

2.3 Duelist Algorithm (DA)
Duelist Algorithm (DA) is an evolutionary computation technique inspired by how duelist improve their capabilities in a duel that was developed by Biyanto, et al. in 2016 [11]. The algorithm is tested by using 11 different optimization problems and the result shows that the proposed algorithm is able to surpass the other recent stochastic algorithms and present robust results.

2.4 Killer-Whale Algorithm (KWA)
Killer-Whale Algorithm (KWA) is a new evolutionary computation algorithm that is inspired by the life of Killer Whale that was developed by Biyanto in 2016. KWA is tested by using 6 objective function containing Gaussian noise, Uniform noise and Seldom Cauchy noise, the results obtained from this test are compared with algorithm such as CMA-ES, GA, ICA and SA. The results show that the KWA is able to outperform the four algorithms used for comparison with a success rate as much as 4 of 6 objective function in 5 and 20 dimensions [12].

2.5 Rain-Water Algorithm (RWA)
Rain-Water Algorithm (RWA) is a new algorithm that is inspired by the pattern of physically rain water movements from air to the lowest place on the earth that was developed by Biyanto in 2016. The results show that the Rain-Water Algorithm is able to outperform the four algorithms used for comparison in term of speed of convergent [13].

3. Research Method
In this research, an office building was optimized using GBCI standard. The optimized variables were 154 glass types and 3 insulation types. The objective function was calculated using equation (7) as follows:

$$\text{Obj. Function} = \text{Max ROI} \quad (7)$$

Cost of extra investment for the building was calculated based on 2013 market prices and tabulated in Table 2 [14].

Table 2. Cost of water consumption and other cost of investment

Description	Cost
Cost of water consumption	154,053,075 IDR
ASD cost of investment	490,875,000 IDR
MRC cost of investment	898,475,000 IDR
WAC cost of investment	1,063,592,524 IDR
IHC cost of investment	76,100,000 IDR
BEM cost of investment	630,000,000 IDR

Source: Biyanto, et al., 2013

In general, the flow chart of research methodology is shown in Figure 1.

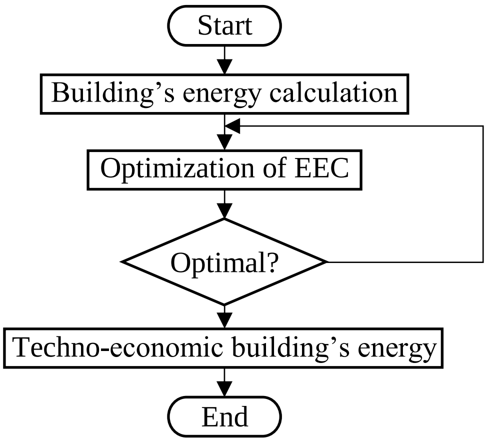

Figure 1. EEC optimization flow chart

4. Results and Discussions

In this research, Duelist, Killer-Whale and Rain-Water Optimization Algorithms were used to optimize ROI in green building design. These algorithms exhibited similar optimization results, as it may be due to the optimization problem which can be classified in simple problem. Hence, in the rest of discussions, the optimization results were provided from those optimization algorithms. The simulation of artificial lighting using LED lamps Philips Core-Line Batten Module 40 W type (BN120CL1200 1Xled38S/830) for each floors is shown in Figure 2. Figure 2 shows that most of artificial lighting area was above 350 lux and it was met with SNI 03-6575-2001 standard. The average of electrical consumptions due to lighting load of all floors was 5.80 W/m^2.

Table 3. Combination the chosen design of any EEC

EEC Point	Design Combination		ROI
	Type of Glass	Insulation	%
14	Panasap Dark Grey (3 mm)	Glasswool	30.2424
15	Panasap Green (5 mm)	No Insulation	31.9647
16	Planibel G (3.2 mm)	Glasswool	36.8486
17	Panasap Green (8 mm)	Glasswool	29.5671
18	Sunergy Green (6 mm)	Glasswool	20.6389

19	Stopsol Blue Green (6 mm) + Air + Clear (6 mm)	Glasswool	18.7667
20	Stopsol Green (8 mm) + Air + Planibel G (6 mm)	Glasswool	15.1297

The results of optimization show that the combination of the type of glass and insulation results different EEC points and ROI as shown in Table 3.

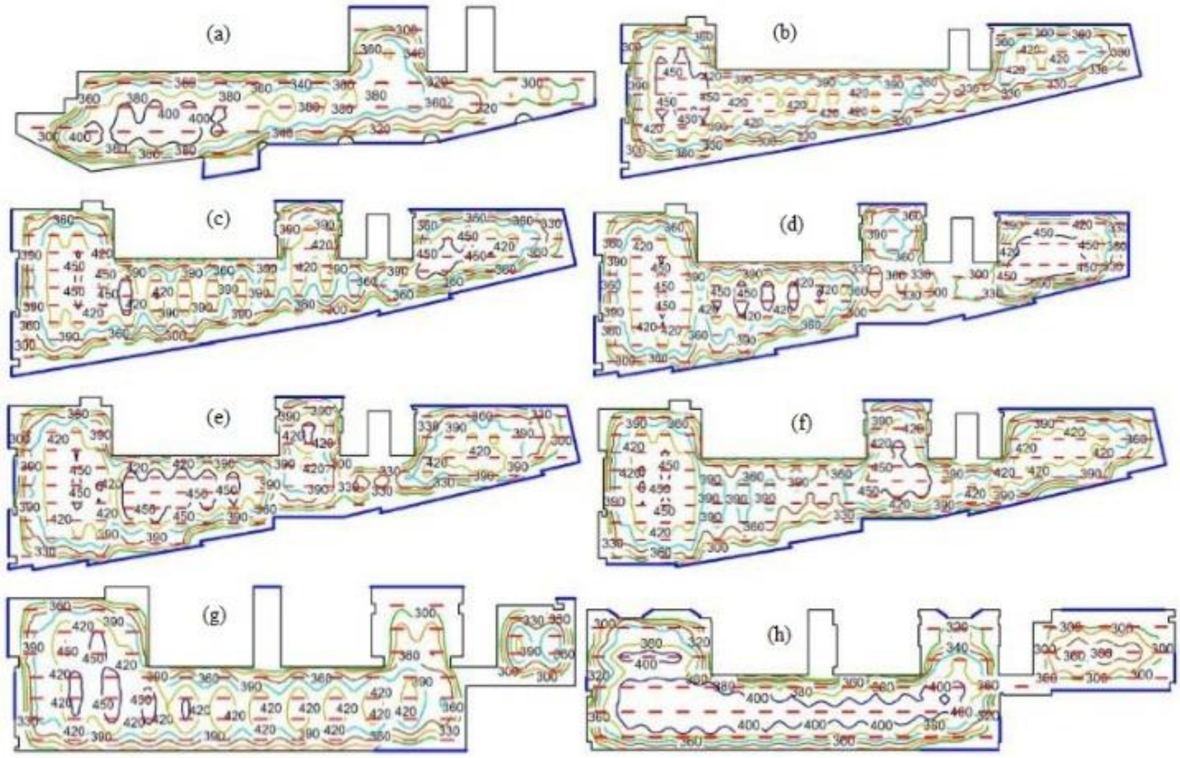

Figure 2. Artificial lighting at (a) ground floor and mezzanine floor, (b) 2nd floor, (c) 3rd floor, (d) 4th floor, (e) 5th floor, (f) 6th floor, (g) 7th floor, and (h) 8th until 16th floor

Table 3 shows that the EEC 16 point has maximum ROI value of 36.8486%. Meanwhile, the EEC 20 point has lower ROI than the EEC 16 point. The amount of Energy Use Intensity (EUI) also affected by EEC point as shown in Figure 3.

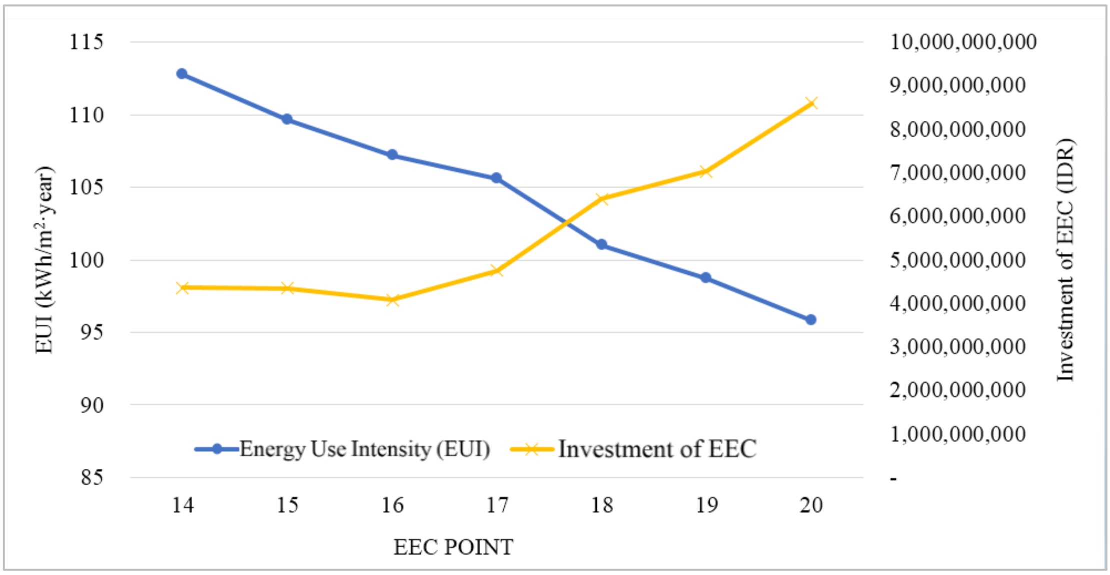

Figure 3. EUI and investment for any EEC points

Table 4 shows that the results of optimization has lower cooling load and EUI than the baseline building. The amount of EUI also affect the amount of CO_2 emission from the building. From an economic of view, the optimization results provide lower investment due to decreasing the price of the cooling system and glasses.

Table 4. Comparison between building baseline and optimization

Description	Unit	Comparison	
		Baseline	Result
Cooling System Capacity	TR	242.84	200.11
EUI	kWh/m^2·year	161	107
CO_2 emission	tons/year	1456.195	969.298
Cost of Investment Cooling System	IDR	1,457,069,420	1,200,675,063
Cost of Investment CHWP	IDR	118,110,930	66,088,490
Cost of Investment CWP	IDR	73,819,331	41305307
Cost of Investment AHU	IDR	188,443,896	93751561
Cost of Investment Glass	IDR	1,455,111,856	335,795,044
Cost of Investment Insulation	IDR	-	27,750,000
Cost of Investment Lamp	IDR	1,522,320,000	2,218,500,000
Cost of Investment ESM	IDR	-	24,000,000
Cost of Investment Lux Sensor	IDR	-	71,040,000

5. Conclusion

In this paper, Duelist, Killer-Whale and Rain-Water Optimization Algorithm were used to optimize EEC in green building design. The single glass Planibel G with 3.2 mm thickness and glasswool insulation were chosen as optimized variable that provided maximum ROI of 36.8486%, EUI reduction of 54 kWh/m^2·year, CO_2 emission reduction of 486.8971 tons/year and reduce investment of 4,078,905,465 IDR due to lower investment in the cooling system and glass.

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