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In Malang, Indonesia, a techno-economic analysis of hybrid energy systems in public buildings

Mochammad Junus[1,2], Marjono[3], Aulanni'am[4], Slamet Wahyudi[5]
[1]Environmental Science Doctoral Program, Brawijaya University, Malang, Indonesia
[2]Department of Electrical Engineering, State Polytechnic of Malang, Malang, Indonesia
[3]Department of Mathematics, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, Indonesia
[4]Department of Chemistry, Faculty of Mathematics and Natural Sciences, Brawijaya University, Malang, Indonesia
[5]Department of Mechanical Engineering, Faculty of Engineering, Brawijaya University, Malang, Indonesia

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ABSTRACT

Because of the fickle nature of the renewable sources of energy production, professionals in this sector have developed hybrid renewable energy systems (HRES) that offer a constant and stable load supply. This research intends to build off-grid hybrid energy systems (HES) in Malang, Indonesia, that uses a solar generator, wind turbine, and biogas to power public buildings. The HOMER program was used to construct this model. Following the computations, multiple hybrid renewable energy system models are used to analyze each component's capital cost and also cost of energy (COE). Furthermore, energy output, gas emissions, and a thermoeconomic assessment of several HRES models have been explored. Two ideal HRES models were evaluated: one with a biogas generator and one without. According to the research, employing a generator of biogas would reduce fuel consumption and emissions by 68.3%. This HRES model is impressive in light of Malang's severe air pollution. Switching from diesel to biogas generator decreases NPC by 6.84%, according to the data.

Corresponding Author:

Mochammad Junus
Department of Electrical Engineering, State Polytechnic of Malang
Malang 65141, Indonesia
Email: mochammad.junus@polinema.ac.id

1. INTRODUCTION

Globally, energy consumption is growing. Alternative energy systems have aroused global interest due to diminishing fossil fuel supplies and rising greenhouse gas emissions [1], [2]. The most significant downside of using sources of energy is their inconsistent rate of production [3]-[5]. In this case, power production instability is inescapable [6], [7]. This has an impact on the dependability of off-grid power systems [7], [8]. The new of technologies have permitted the implementation of energy alternative of hybrid energy system that incorporates the generator to meet load needs for the least amount of money feasible. RES and conventional generators are integrated into modern systems (diesel, gas, or microturbine). Hybrid technology may improve the dependability and efficiency of power generation by integrating generators, energy storage devices, and renewable energy sources. Energy production stability [3], [9]-[11]. In general, while selecting a suitable hybrid model, two important factors should be considered: dependability and cost-effectiveness. It is vital to choose components systems with adequate capacity (NPC) to improve hybrid system efficiency while reducing net present cost [12].

In this experiment, hybrid optimization of multiple energy resources (HOMER) [13] is employed. The fundamental aspects of modeling methodologies include simulation, optimization, and sensitivity analysis

[14]-[16]. By finding alternate energy supply sources and life cycle costs, the HOMER computer will simulate hybrid energy system performance hourly each year [17], [18]. To determine the minor feasible life cycle of a variety of different power supply arrangements that fulfill technical limitations are studied [16]. Hybrid renewable energy systems (HRES) modeling has gotten a lot of attention. Around 60% of this research sector is carried out in Asia, with photovoltaics (PV) accounting for 91.2% of all HRES. So that, 67.3% of the studies employed wind turbines, while 17.3% using hydro turbine. So that, generators (microturbine or diesel) are used in roughly 80% of HRES systems [19]. Biogas generators are a hybrid energy source that has received minimal attention in Indonesia. Despite Indonesia's vast biogas potential, the majority of research has focused on wind turbines and hybrid diesel generators.

2. METHOD

2.1. System of hybrid energy

Generators are widely used in system of distributed off-grid because of their high dependability, cheap cost and also simple of installation [20]. Due to high fuel supply and distribution expenses, as well as depreciation, using generators is difficult. Wind and solar energy may be utilized to cut down on the quantity of fuel used and pollutants emitted [21], [22]. Integrated wind turbines [23], solar panels with generators have minimal maintenance costs, are silent, and are simple to install (particularly in Indonesia). Apart from the challenges of microgrid islanding caused by unexpected and uncontrolled production and demand changes, wind, and solar systems are also utilized. Due to significant seasonal wind speed fluctuations, wind turbines cannot consistently offer electricity to long-term consumers. Furthermore, owing to a lack of sunlight at night and decreased power production in gloomy circumstances, off-grid solar systems cant be considered a stable source of energy. To solve this problem, we'll need a lot more wind turbines, solar panels, and generators, which will be quite costly. This energy storage system (batteries) may increase system performance when combined with additional components [24]-[26]. Hybrid systems, as previously stated, may reduce the costs and emissions connected with the use of fossil fuels. This study is used to model and optimize a hybrid energy system as shown in Figure 1.

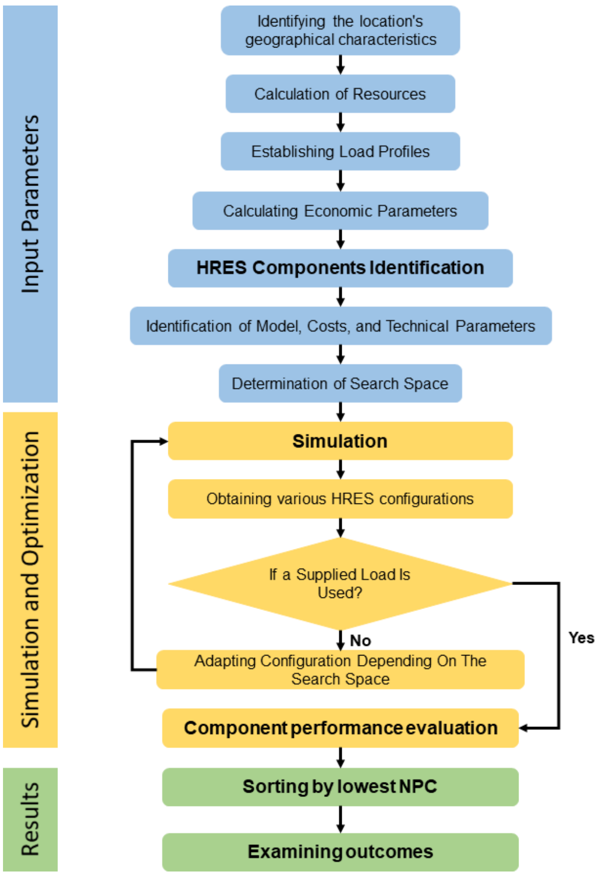


Figure 1. Problem algorithm for HRES

2.2. Load profile

To determine the technical and economic viability of production systems of hybrid energy for these buildings, as good as the possibility of putting them in place. Malang is located at 7.98129825°S 112.63192625°E in the province's center Figure 2. Malang is around 445-556 meters above sea level. The average solar radiation and wind speed for the whole year are 5.17 kWh/m^2 and 4.36 m/s respectively Figures 3(a) and (b). The power usage of electrical equipment was calculated using figures from the State Electricity Company (PLN) for the year 2021 [27], [28]. According to the findings, the average of daily demand for The total energy use is 33.64 kWH, with an average consumption of 8.11 kW. Every time HOMER receives data, as a consequence, 8.760 is divided by the total yearly consumption. The load is shown in Figure 4.

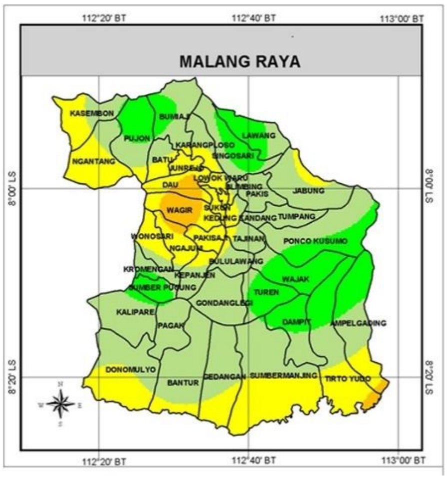
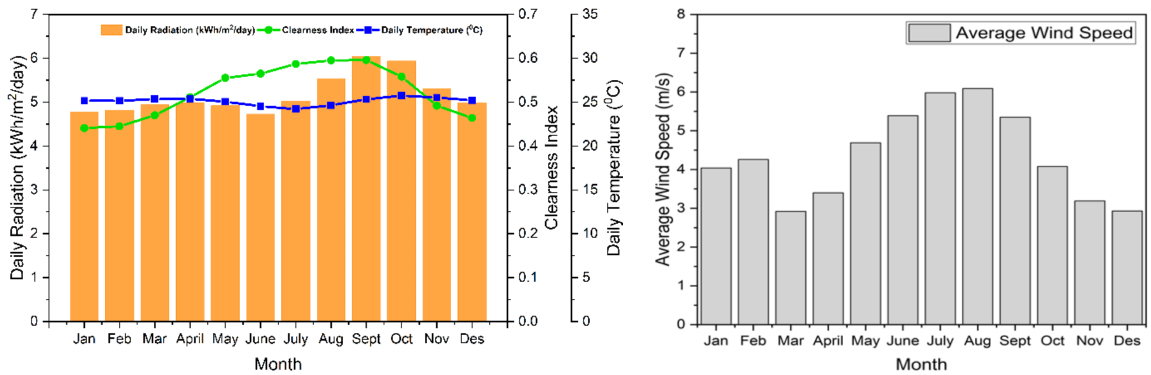


Figure 2. Map of Malang city



(a) (b)

Figure 3. Daily radiation and average wind speed (a) daily radiation figure temperature, clearness and solar radiation index and (b) average wind speed

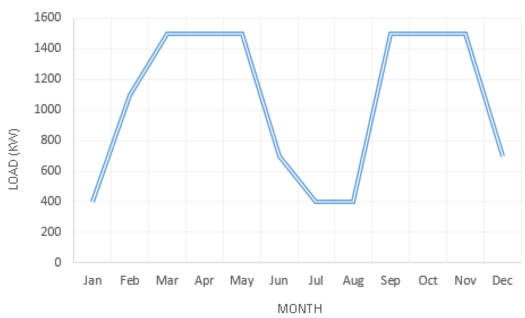


Figure 4. Load profile

2.3. Economic parameter modelling

An economic theory is the most important parameter in HOMER's simulation and optimization techniques. The NPC is used by the HOMER program to calculate the lifespan cost of a system, which includes capital investment, operating and maintenance expenses, replacement costs, environmental fines, fuel costs, and money from grid sellback. In the NPC calculation, costs are represented as positive numbers, while profits are represented as negative ones. HOMER can detect potential difficulties by applying a consistent discount rate to all spending and revenues throughout the year. It is necessary to apply the effect of the actual annual discount rate to the NPC after it has been subjected to a systematic analysis technique in order to acquire the desired outcome. HOMER obtains the real discount rate I from (1).

$$i = \frac{i' - f}{1 + f} \tag{1}$$

The nominal interest rate is I and the expansion rate is f. Capital, process, changeover, repairs, energy, a penalty of environmental, and other expenditures not covered by revenue, such as salvage value, are all included in HOMER's yearly cost per component calculation. For the course of the project, this number may be used to calculate the NPC for individual components and the total system (2).

$$C_{NPC} = \frac{C_{ann,tot}}{ECR(i, R_{pro})} \tag{2}$$

where C_{ann}, tot is the total yearly cost of a hybrid system, ECR is the element of capital recovery, and R_{pro} is the scheme's duration. The capital recovery factor is defined as (3):

$$ECR(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1} \tag{3}$$

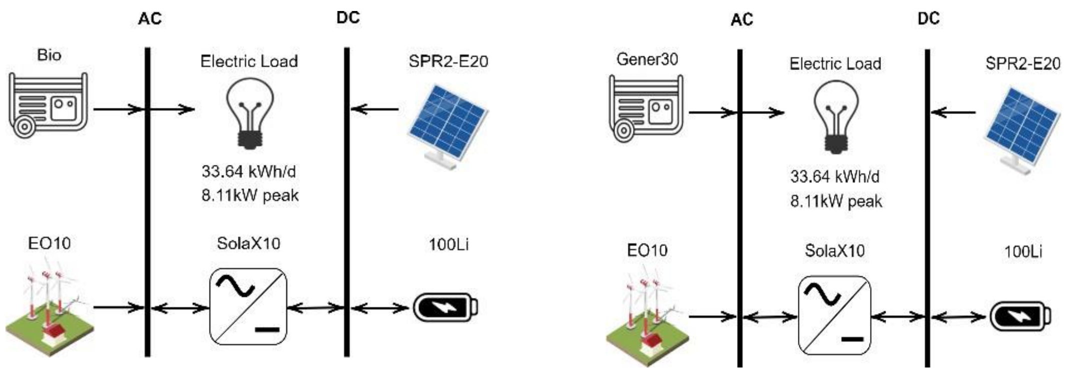
where N is the number of years. In (4) is used in HOMER to compute the levelized cost of energy.

$$LCOE = \frac{C_{ann,tot}}{E_{prime} + E_{def} + E_{grid,sales}} \tag{4}$$

Inflation is expected to be 1.6% in 2021, with a nominal discount rate of 3.5%, according to Bank Indonesia. The project will endure for 20 years.

2.4. Component's system of hybrid

A hybrid energy system is seen in Figure 5. Figure 5 hybrid renewable energy systems. Renewable energy system using PV or wind or biogas for Figure 5(a) and using PV or wind or diesel for Figure 5(b). Also Figure 5 depicts the system's equipment characteristics and selection criteria.



(a) (b)

Figure 5. Hybrid renewable energy systems (a) using PV/wind/biogas and (b) using PV/wind/diesel

2.4.1. Photovoltaic solar system

In this research, PV panels were employed in the hybrid energy system. The rated capacity of the PV utilized is 0.327 kW. This solar energy source is exceptionally good in contrast to other solar energy sources in the HOMER; the E20-327 is 20% efficient. PV panels are said to have a 25-year life expectancy, according to manufacturers. Capital, changeover, and process-repair expenses for PV panels are $2000 per kW, $1200 per kW, and $30 per year, respectively. Ground reflectance of 20% and consistent horizontal and vertical tracking are among the simulation's characteristics.

2.4.2. Energy system of wind

The energy curve, hub height, longevity, and economic data are all factors that are taken into consideration while modeling turbines. Malang has an average wind speed of 4.36 m/s. Because of its efficiency, the Recycle EO10 wind turbine from the HOMER library was selected for simulation in this work. A 10 kW wind turbine in Malang produces one of the cleanest forms of electricity. HRES employed a horizontal axis turbine from Canada in this research. It's also 16 meters tall, making it perfect for both urban and rural settings. The wind turbine has a 20-year lifespan and generates AC electricity. Repairs and maintenance cost 50 dollars each year.

2.4.3. Generator of diesel

The Generac 30 kW protector (RD030) guarantees that energy is delivered dependably with a 15,000-hour life and 1.15 liter of fuel usage per hour. The initial investment is 13,999 dollars [29], [30], and the operating and maintenance costs are 0.6 dollars per hour. In Indonesia, diesel costs 9,500 Rupiah (0.66$) [31].

2.4.4. Battery

Batteries become necessary when renewable energy sources are unavailable. The quantity of solar panels, wind vane and generator necessary determines the number of batteries required. PV cells are solar cells that generate electricity. The energy storage's voltage is crucial. The nominal voltage, capacity, and lifespan curve for each battery in HOMER are unique to that battery. For this test, we're utilizing a Surrette 6CS25P battery. It may also be used to figure out the needed of batteries a hybrid system.

2.4.5. Software application tool

HOMER Pro was used to assess the optimum hybrid microgrid architecture (3.14.5). Hourly energy balance and feasibility studies may be performed on remote, autonomous, and distributed generating systems. Limitation’s system reduces like power balancing and demand management and renewables penetration to get the lowest NPC. Predictive dispatch, LF, CC, and CD (PS). It is necessary to do a pre-HOMER analysis. Based on research and personal judgment, an initial evaluation of yearly electrical load demand was made. This information was gathered from a variety of sources. HRES is responsible for the microgrid system model software and cost data. Pre-HOMER rated program for techno-economic analysis.

3. RESULTS AND DISCUSSION

Here are the technics and economic also environment aspects of the best of hybrid system. HRES-1 has 30 kW of solar panels, a 10 kilowatt of generators biogas, 2 units of battery and a 2.67 kW converter of electrical. The NPC is 228,970$, and the COE is 1.23$. Although acquiring a wind turbine raises capital costs, it reduces fuel use and pollution by 57%. The aforesaid emissions are raised to 7.49 kg CO_2 with HRES-2 (30 kW solar, 10 kW biogas generator, two batteries, and a 10 kW electrical converter). Given this, there isn't much of a difference between HRES-1 and HRES-2.

The best model is determined by the user's goal and the environmental difficulties in the target location. Due to severe air pollution, environmental concerns are critical in Malang. HRES-1 was selected for this inquiry despite its greater initial cost. The wind turbine provides 77.5% of the electricity, the biogas generator 17.3%, and the PVs 5.2% in the selected system. In other words, the turbine, generator, and PVs generate 48,960, 11,443, and 3,152 kWh per year, respectively. Wind turbines dominate capital costs in the proposed paradigm, whereas biogas producers dominate replacement and fuel expenses. The Biogas generator should be replaced every 14 years, and the battery should be replaced every 12 years. Table 1 show HRES overall costs and revenues for each aspect and Table 2 show cost simulation results with diesel generator 30 kW and converter 10kW.

The cost of capital is 184,538 dollars, operation and also the maintenance is $6,479, substitution is $52,716, and recovery is $28,463.35. Figure 6 show the yearly load summary and total power generation of each system module and Figure 7 cumulative discount cash flow for a hybrid renewable energy system. The wind turbine runs at less than half capacity for 6,928 hours each years, while solar PV run for 4,387 hours. Sunlight exposure affects the quantity of energy created before and after 7 a.m. PV electricity is useless during the wet season. Generator of biogas runs for 1,127 hours and uses 8,006 m^3 of biogas throughout that time. This mechanism is most active at night and generator also generates power at the start and end of the year. Table 3 show energy systems emissions.

Table 1. HRES's overall costs and revenues for each aspect

Module	Capital($)	Replacement($)	O&M($)	Salvage($)	Total($)
Eocycle EO10	29.000	12.610	760.98	7.686	34.692
Generic biogas genset	90.000	37.249	2,371	20.580	10.040
Sola X3-hybrid10	3.080	0	3,043	0	6.123
SunPower E20-327	60.000	0	0	0	60,000
Surrette 6 CS 25P	2.400	2.849	304	197	5.414
HRES-1	184.500	52.716	6.479	28.463.35	215.270

Table 2. Cost simulation results with diesel generator 30 kW and converter 10kW

Scheme	PV (kW)	Wind turbine (quantity)	Battery (quantity)	NPC ($)	COE ($)	Operating ($/yr)	Capital ($)	Fuel ($/yr)
6	30	1	2	244.643	1.31	8.943	108.637	1.733
7	30	-	2	489.123	2.62	26.912	79.537	5.802
8	-	3	1	726.510	3.89	40.816	105.308	8.913
9	-	-	-	1.32M	7.06	85.733	13.999	19.246
10	-	-	1	1.33M	7.10	85.947	18.308	19.226

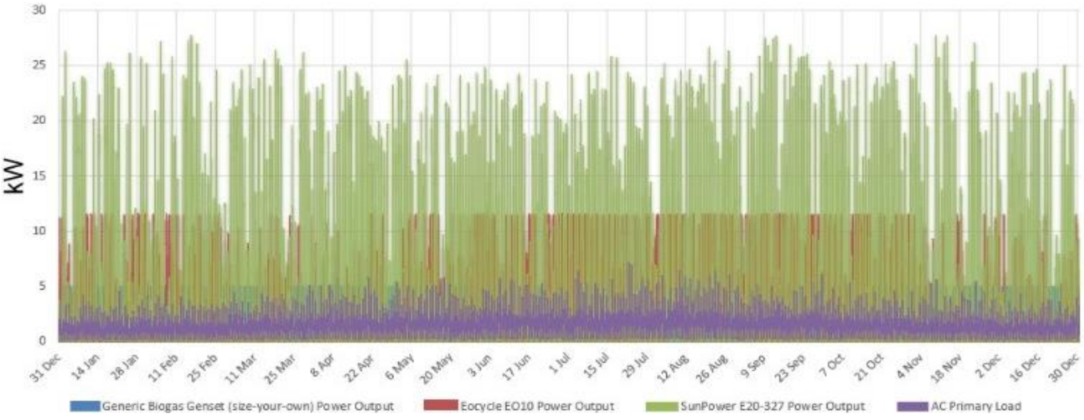


Figure 6. For one year, the summary of total load and power generation

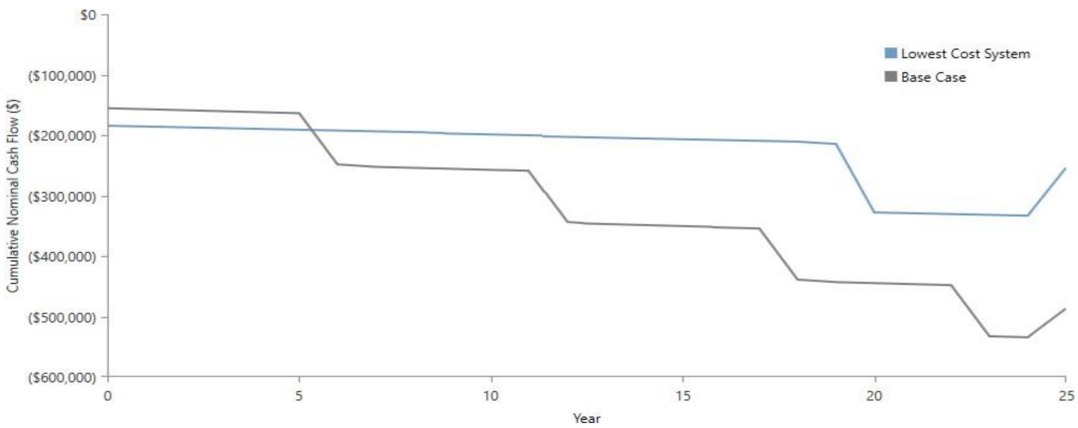


Figure 7. Cumulative discount cash flow for a hybrid renewable energy system

Table 3. Energy systems emissions

Quant	PV/wind/biogas generator Value	PV/wind/diesel generator Value
Carbon dioxide (CO_2)	2.21	6.983
Carbon monoxide (CO)	0.0245	42.3
Unburned hydro carb	0	1.92
Particulate matter	0	2.31
SO_2	0	17.1
Nitrogen oxides (NO)	0.0153	57.7

4. CONCLUSION

Despite the fact that HRES-2 has a 36 per cent higher NPC than HRES-1, evidence shows that emissions from the biogas generator have also risen. This is a significant achievement given Malang's high pollution. 77.5, 17.3, and 5.2% of the system's electricity are generated by the wind turbine, biogas generator, and PVs, respectively. The wind turbine dominates the recommended model's capital costs, whereas the biogas generator's operating and replacement expenses are dominated by the biogas generator. The NPC for this model is 228,970$, and the COE is 1.23$. In the majority of HOMER's recommended models, the biogas generator is utilized. Batteries and electrical converters are essential in all hybrid cars due to the unpredictability of renewable energy generation. The results show that when the suggested model includes a wind turbine, this component produces the greatest power, as shown findings. Finally, many researchers examined the hybrid system's techno-economic performance when it was fueled by generator of biogas rather than generator of a diesel.

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BIOGRAPHIES OF AUTHORS

Mochammad Junus received Bachelor of Engineering in Electrical Engineering Department of Engineering Faculty at Institut Teknologi Sepuluh Nopember Surabaya on 1998. He has obtained Master of Engineering from Electrical Engineering Department at Universitas Brawijaya on 2007. He is working as senior lecturer in Department of Electrical Engineering at Politeknik Negeri Malang. He focuses on the fields of renewable energy and telecommunications electronics. He can be contacted at email: mochammad.junus@polinema.ac.id.

Marjono received Bachelor of Science in Mathematics Department FMIPA at Universitas Gajah Mada on 1987. He has obtained Master of Mathematic from Mathematics Department at Swansea University on 1993. He has obtained Doctor of Philosophy of Mathematic from Doctoral School of Mathematics and Scientific Computing at TU Graz on 1999. He is working as senior lecturer in Department of Mathematics at Universitas Brawijaya. He focuses on the fields of introduction to complex functions, univalnt functions functional analysis, capita selecta analysis, and science. He can be contacted at email: marjono@ub.ac.id.

Aulanni'am received Bachelor in Bachelor of Veterinary Medicine of Faculty of Veterinary Medicine at Universitas Airlangga. She has obtained Master from The Lille University of Science and Technology. She has obtained Doctorate (Dr.) degree from Faculty of Medicine at Universitas Airlangga. She is working as senior lecturer in Faculty of Medicine at Universitas Brawijaya. She focuses on the field of biomedical system. She can be contacted at email: aulani@ub.ac.id.

Slamet Wahyudi as born in Jember, Indonesia on 3th of September 1972) is an Associate Professor in the Department of Mechanical Engineering at Brawijaya University, Indonesia. He is a Head of Laboratory of Solar and Renewable energy. He got his Dr. in Medical Engineering from Brawijaya University in 2006, He has published a lot of journals in the field of energy conversion and numerical analysis. His areas of interest are bioheat, fluid mechanics, and numerical method. He is keen to collaborate with other researchers. He can be contacted at email: slamet_w72@ub.ac.id.